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Laserlab Forum

Newsletter of LASERLAB-EUROPE, the integrated initiative of European laser infrastructures funded by the Seventh Framework Programme of the European Community

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Editorial

Time flies when you are having fun! Even though LASERLAB-EUROPE II only started in the spring of 2009, the proposal for the third phase (which should start in 2012) has already been submitted to the European Commission. Meanwhile, the scientific LASERLAB community does not stand still. As can be read in this tenth edition of Laserlab Forum, once again several of our outstanding researchers have been awarded prestigious Advanced Grants by the European Research Council, underlining the quality of researchers present within the expanded consortium.

However, there is no time to rest on our laurels. We need to think about the young people who will someday have to replace the current generation of laser scientists. That is why, in order to help students and young researchers on their way to excellence, LASERLAB-EUROPE participates in several Marie Curie and Erasmus Mundus programmes. These European initiatives give young, talented people the possibility to expand their horizons while spending some time abroad in a stimulating environment.

We hope that, despite the inevitable busy daily activities, you will find time to read this Laserlab Forum to get a jest of what is happening within LASERLAB-EUROPE today. Have a good time!

Tom Jeltes

News

Advanced Grant for study of particle acceleration in relativistic shocks

Dr. Luís Silva, Instituto Superior Tecnico (IST, Lisbon), has been awarded an Advanced Grant from the European Research Council to explore particle acceleration in relativistic shock waves driven in astrophysical scenarios or by ultra-intense lasers.

The team of Luís Silva at GoLP/Instituto de Plasmas e Fusão Nuclear at IST, one of the new partners in LASERLAB-EUROPE II, aims to study and to identify the key mechanisms for particle acceleration in relativistic shocks with massively parallel numerical simulations.

It has been proposed that acceleration in collisionless shock waves is the critical mechanism for the acceleration of cosmic rays, the most energetic particles in the Universe, but the acceleration mechanisms in these nonlinear waves remain to be clearly identified. The work to be developed in the ERC Advanced Grant "Accelerates" aims to understand the physics underlying shock formation and the microphysics determining particle acceleration in relativistic shocks.

The IST team will also address the possibility to generate these shock waves using ultra intense lasers with the goal of further exploring shock acceleration in laboratory conditions and of harnessing shock acceleration to optimize novel laser-based energetic particle sources.

Anne L'Huillier wins Award for Women in Science

Prof. Anne L'Huillier (LLC) has won one of the five 2011 L'Oréal-UNESCO Awards for Women in Science. This was announced by the jury on November 9, 2010. She will receive US $100,000 in recognition of her contribution to science.

Five outstanding women scientists, one per continent, are honoured each year "for the contributions of their research, the strength of their commitments and their impact on society". This year's laureates were selected in the Physical Sciences domain; Anne L'Huillier received the award for the European continent. She is a professor of Atomic Physics at Lund Laser Centre in Sweden, and is currently conducting research on attosecond control of light and matter supported by an ERC Advanced Grant that she obtained in 2008.

Advanced Grant for research on photosynthesis

Prof. Rienk van Grondelle (LaserLaB Amsterdam) received an ERC Advanced Grant of almost 3 million euro, which will fund his research into the role chlorophyll-binding proteins play in determining the success of photosynthesis.

The research will hopefully lead to the implementation of photosynthesis in food and/or fuel production. The biological machine driving photosynthesis comprises an intricate constellation of pigment-protein complexes that includes chlorophyll and carotene. The success of photosynthesis depends on ultrafast events (on the order a picosecond), in which solar energy is converted into electrical energy. The study will be conducted using ultrafast and other spectroscopic techniques housed at the LaserLaB Amsterdam and the CEA Saclay, where part of the project will be carried out in collaboration with Dr. Bruno Robert.

Cover photo: Multi-mirror set-up of a laser amplifier at MBI. Photo: Uwe Bellhäuser

LaserLaB Amsterdam goes beyond Standard Model

The Atomic, Molecular and Laser Physics group of LaserLaB Amsterdam (the former LCVU) has received a Dutch grant of 2.9 million euro for the programme 'Broken Mirrors & Drifting Constants'. The programme will be led by Prof. Wim Ubachs. LaserLaB will collaborate with the KVI institute in Groningen (NL) in precision experiments on atoms, ions and molecules, aiming to uncover physics beyond the Standard Model.

In Amsterdam, a laser with a linewidth of 1 Hz will be built to facilitate frequency measurements with a 15-digit accuracy and better. This might allow detection of time-dependence of constants of nature such as the proton/electron mass ratio or the fine structure constant. In addition, precision tests of quantum electrodynamics in helium are planned and experiments will be set up to find indications of parity violation. As part of the programme, a fiber link for transmission of ultra stable optical signals for comparison between atomic clocks will be established between Amsterdam and Groningen. This fiber link will later be incorporated in a European fiber network.

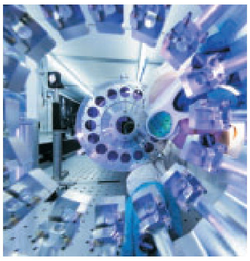
Attosecond physics in the picture

On October 26, 2010, national Spanish newspaper El Pais highlighted the Attoscience and Ultrafast Optics lab at ICFO as one of the few places worldwide which have generated and measured attosecond pulses.

An attosecond resolution camera is fast enough to track movements of electrons inside atoms and molecules. Potential applications are to improve our understanding and control of chemical reaction pathways, to unravel the inner workings of protein folding, and to offer new techniques to dynamic biological imaging. The group led by ICREA Prof. Jens Biegert works in a highly interdisciplinary field which fuses ultrafast laser physics, extreme nonlinear optics, atomic and molecular physics, XUV synchrotron optics, UHV technology, and electron-ion coincidence imaging techniques.

Higher performance for high-power lasers

Either with enormous pulse energy or with high repetition rate – this might describe the present state of the art of laser technology. Scientists of the Max Born Institute (MBI) in Berlin, in close cooperation with diode laser specialists of the Ferdinand-Braun-Institute (FBH), plan to combine the two properties. The goal are lasers which reach high single-pulse power at 100 shots per second or more. For the development of such novel lasers the scientists have obtained a grant of 3 million Euros from the European Union (European Fund for Regional Development – EFRD), the total volume of the project being 6 million Euros.

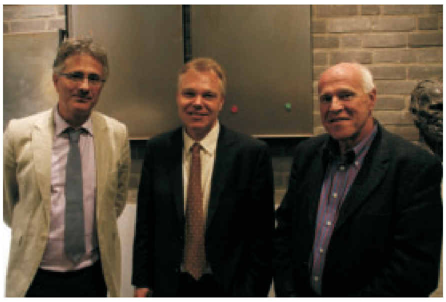


Multi-mirror set-up of a laser amplifier at MBI. Photo: Uwe Bellhäuser

Farewell LCVU, welcome LaserLaB!

LCVU Amsterdam expands and is renamed LaserLaB

The LCVU (Laser Centre Vrije Universiteit) Amsterdam is no more. After 18 years, the Dutch partner of LASERLAB-EUROPE has reached adulthood and transformed into LaserLaB Amsterdam, the Institute for Lasers, Life and Biophotonics. The expanded institute now also includes physicians and will focus on the multidisciplinary topics Human Health and Energy.



Wim Ubachs, Johannes De Boer and former director Wim Hogervorst

On October 22nd, the transformation was celebrated ceremonially with a symposium held in the home base of the Royal Netherlands Academy of Arts and Sciences (KNAW), in the old city centre of Amsterdam.

The new institute includes all laser-oriented research groups from the VU University Amsterdam that made up LCVU, but LaserLaB is now expanded with groups from both the VU University Medical Center and the University of Amsterdam and its Medical Center, AMC.

LaserLaB is led by Prof. Johannes de Boer (head of the pivotal interdisciplinary Complex Systems group, VU University), who has taken over from Prof. Wim Ubachs. The activities of the institute are divided up in seven new scientific programs that between them address two important societal needs: Human Health and Energy.

LaserLaB Amsterdam

Institute for Lasers, Life and Biophotonics

By including the two academic medical centres in LaserLaB, physicians will be added to the existing mix of physicists, chemists and biologists, thereby stimulating translational research (research leading to the actual treatment of patients). LaserLaB will focus on developing optical methods and instruments to study the interaction between proteins, DNA, cells and tissue, providing knowledge that will likely lead to innovative diagnostic tools and therapeutic techniques.

User Training Workshop and Latin Laserlab in Salamanca

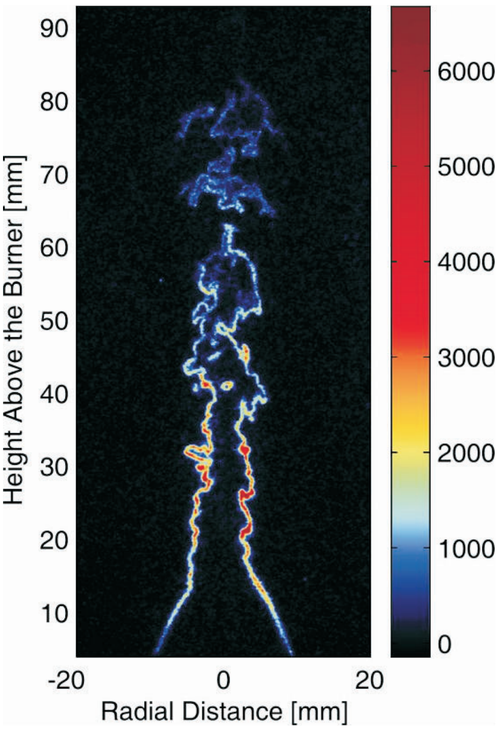
A training workshop for users of high power laser facilities, organized by CLPU, took place in Salamanca on 8 and 9 of November. The workshop was attended by experts on high field physics as well as representatives from ELI, LASERLAB-EUROPE and the LASERLAB users' community, attracting a large number of attendees, mainly Spanish PhD and master students.

Salamanca was also host to the first "Latin LaserLab" workshop, aimed at establishing links between LASERLAB-EUROPE and the Laser Community in Latin America. This meeting took place on 11 and 12 of November and brought together students and researchers from Argentina, Brazil, Mexico, Colombia, Panama, Portugal, Venezuela and Spain.

Using lasers to study combustion

Currently, over 90% of the energy we use for transport, heating, and electricity production is generated by burning fuels. Considering that combustion emissions also constitute the main source of air pollutants, understanding the combustion process is crucial. Not only to enhance the efficiency of energy generation, but also to reduce the amount of pollution resulting from burning (fossil or renewable) fuels. Prof. Dr. Marcus Aldén, who heads the Combustion Physics Group of Lund Laser Centre in Sweden, has used lasers to study the details of combustion processes since the late seventies. He recently received an Advanced Grant of 2.5 million Euro from the European Research Council, to extend his research in this highly relevant field.

Lasers provide a convenient non-intrusive technique with which the combustion process can be followed with high spatial and temporal resolution, says Marcus Aldén. At Lund University, he collaborates extensively with combustion engineers, who operate over ten engines specially equipped with transparent windows – allowing laser beams to perform their diagnostic tasks. "We also have a high pressure burner which occupies a building of its own, and which operates at near industrial conditions. The laser measurements we perform in this burner provide a database that is used by modelers we cooperate with."



Visualisation of CH in a turbulent flame

Part of Aldén's research is concerned with rather fundamental physics and he stresses that being part of the Lund Laser Centre is an important complement to the more industrial combustion connections. "We try to find out what will happen with atomic and molecular spectra at temperatures of 3000 Kelvin and pressures of 50-60 bars. It is a highly demanding task to understand the influence of these extreme conditions on non-linear spectroscopic techniques, but it is important since those conditions may prevail in actual industrial gas turbines or engines." The Swede collaborates closely with several industrial partners, but it is hard to find funds for the fundamental research needed to analyse combustion processes. "That is why I am particularly happy with this European grant."

Due to turbulence, the conditions in the combustion flame vary rapidly in time and from one place to another. Therefore, it is important to obtain a spatial resolution higher than the typical length scale of the turbulence, which is of the order of micrometers. Furthermore, variations in temperature, density and species concentration occur on a microsecond time-scale. "So far, we used mainly nanosecond laser pulses, which are short enough, but due to the low repetition rate of the lasers, we had to wait 100 ms between each shot. In the mean time, the conditions at that particular point in the flame will have changed." For that reason, Aldén will invest part of his Advanced Grant in new 'high rep-rate' laser systems.

Prof. Marcus Aldén

Another important line of research comprises several types of infrared spectroscopy. Many of the chemical species present in the flames – mainly small molecules, such as water, carbon dioxide, methane, and ethane – hardly absorb light from both the ultraviolet and visible part of the spectrum. Aldén is planning to extend his work on polarization spectroscopy, a method in which the absorption is measured at the spot where two laser beams cross, into the infrared domain. "So far, people have only performed line of sight measurements in the infrared, which is of limited use when temperature and species concentration may change in space and time."

Infrared spectroscopy can be used to detect species, e.g., hydrochloric acid, and hydrogen cyanide, which are present in the flame in low concentrations but have strong absorptions in the infrared. These species play crucial roles in some types of combustion. Finally, Aldén would like to take his research to higher dimensions: "We will also do 2D measurements using an unfocussed probe beam crossed by a sheet shaped pump beam, to create a 2D image of the specific flame species probed."

Tom Jeltes

Towards molecular movies

At the Max Planck Institute of Quantum Optics in Garching, Germany, Prof. Ferenc Krausz and his colleagues intend to use ultrafast lasers and electron pulses to record the motion of atoms and electrons in molecules. Last year, Krausz received an ERC Advanced Grant for this ambitious project 'Towards 4D Imaging of Fundamental Processes on the Atomic and Sub-Atomic Scale', which should provide more insight into fundamental processes of life and matter.

It is one of the remaining holy grails of science: a device with which molecular processes can be followed on a subatomic scale. A kind of video camera, not only able to zoom in to the level of atoms and beyond, but also fast enough to track the ultrafast motion (on a timescale of femtoseconds) in this microcosm.

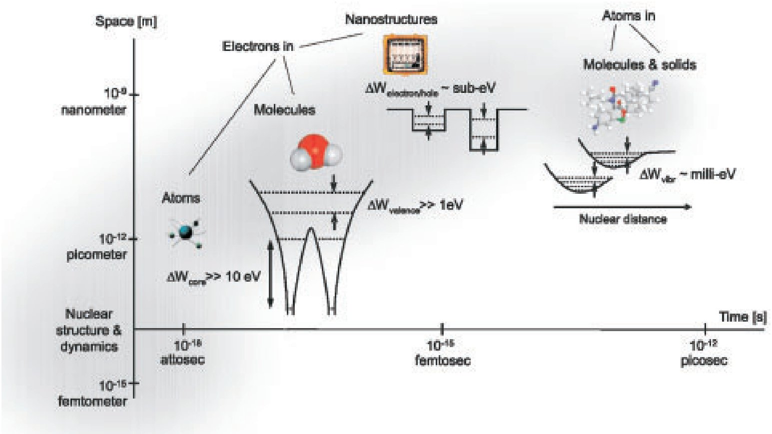
Unfortunately, visible light is useless for this purpose, since the wavelength of light (several hundreds of nanometers) is much larger than the scale at which atomic processes occur. In order to follow atomic and even electronic motion, one needs ultrashort pulses (less than 100 femtoseconds) of hard X-rays or electrons.

X-ray sources based on Free Electron Lasers (X-FELs), such as Stanford's recently installed LCLS and the European XFEL currently being built in Hamburg, do provide opportunities to study molecular processes into great detail by recording 'molecular movies', but these facilities require linear accelerators of several kilometers and huge operational budgets.

Potentially, electron sources of relatively modest size and cost could compete with X-FEL facilities. However, it is notoriously difficult to produce the required picometer sized electron bunches. This is due to the repelling forces the negatively charged electrons exert onto each other. These forces lead to an expansion of electron bunches during their flight towards the object to be studied, and consequently to a worse spatial resolution of the image.

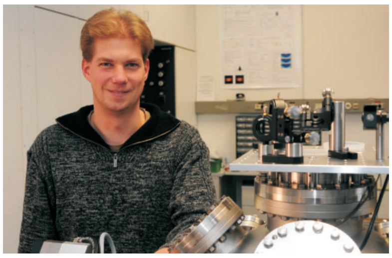
Several thousands of electrons are needed to obtain a diffraction image with a single electron pulse, but in principle one can also integrate data from many subsequent pulses. This is possible thanks to the nature of the recording process: the timing is determined entirely by the delay between the instant the studied molecule is 'reset' with a short laser pulse and the moment the 'probing' electron pulse arrives. For integration to work, the timing of this delay should be accurate enough to assume that each picture contributing to the integration is virtually identical.

In order to avoid expansion of the electron bunches, the Garching group decided to use one electron at a time, thereby getting rid of the blurring effects due to electric repulsion. However, this does not take away all expansion, explains chief investigator of the project, Dr. Peter Baum: "Due to the quantum mechanical spread in momentum of the electron, there is always a spread in the arrival times of the individual electrons. We solve this problem by sending the electron through a microwave cavity which exerts perfectly timed forces onto the electron, forcing the latter part of the wavepacket to catch up, resulting in femtosecond, potentially attosecond electron pulses at the target."

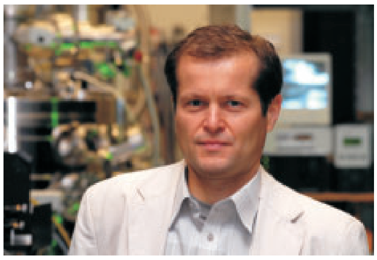


Relevant time scales for atomic and electronic motion in the microcosm.
From F. Krausz, M. Ivanov, "Attosecond Physics", Rev. Mod. Phys. 81, 163 (2009)

Since the relative timing between the laser pump pulse and electron probe determines the time resolution of the 'video camera', an essential part of the project is to perfect the measurement of this delay. For this purpose, the Garching group uses an infrared laser as a streak camera. Baum: "Finding a way to deflect electrons directly by the field cycles of a laser pulse could provide a feedback for jitter suppression on an attosecond time scale".



Dr. Peter Baum



Prof. Ferenc Krausz

Finally, since for each time delay several thousands of electron shots are needed to obtain a picture with sufficient signal to noise, it is essential to fire the shots quickly after each. This requires megahertz repetition rates. Producing waveform-controlled laser pulses at this rate is a huge challenge in its own right. Baum: "The perfect timing and precise compression of the single electrons is provided by the laser field. In that sense, laser technology is but a tool for shaping the electrons up for imaging atoms in motion".

Tom Jeltes

Discussing the future

On 28-29 May 2010, ICFO - The Institute of Photonic Sciences in Barcelona, Spain, hosted the first Laserlab-Europe Foresight Workshop. The two day event gathered Laserlab-Europe partners, representatives from ELI and HiPER, the European Technology Platform Photonics21 and Industry. The focus of the event was 'future challenges for the European laser community: I3's, pan-European research infrastructures and human resources'.

With the ESFRI Infrastructures Europe takes an unprecedented huge step into the future of laser science and technology, but also faces enormous challenges for the European research community in terms of industrial cooperation, human resources, and the necessity for specialist training and mobility actions. The purpose of the workshop was to cover these issues and to help understand which specific problems need to be addressed within Laserlab-Europe and jointly with ELI and HiPER.

The workshop was opened by Wolfgang Sandner, MBI Berlin, Coordinator of Laserlab-Europe, who sketched the present scenario and also stressed the importance of the European Commission's view on the "research eco-system" going forward. The Laserlab-Europe community should maintain strong links throughout the whole research chain from universities to industry, as part of the *2020 Vision for ERA (European Research Area)*. In this respect academia and industry are at the core of the discussions in order to identify how Laserlab-Europe may contribute to the competitiveness of European industry and the Innovation Union. Over 30 participants from across Europe contributed to the workshop.

Day one focused on technical and industrial issues. Laserlab-Europe, ELI and HiPER presented the goals as well as scientific and industrial bottlenecks. Jean-Paul Chambaret, ELI Project Manager, gave an overview of European demands and critical industrial issues concerning ELI's future lasers. Klaus Ertel from Rutherford Appleton Laboratories presented the laser technology challenges concerning the HiPER project which is dedicated to laser fusion energy. He pointed out that the use of diode pumped lasers is mandatory and requires strong interaction with industry.

Vlastimil Ruzicka, Vice Minister for Youth, Education and Sports of the Czech Republic and, Plenipotentiary for ELI-CZ, and Nicolae Zamfir, Director General of IFIN in Magurele (Bucharest, Romania), Plenipotentiary for ELI-RO, present the Czech and the Romanian case for ELI, respectively. In both countries, huge investment for building the research infrastructures are planned which will only be successful when the technological bottlenecks are solved in close cooperation with industry and when the human resources to operate and use the facilities are available.

Industrial participants included Trumpf Laser GmbH & Co KG, DILAS Diodenlaser GmbH and Continuum, who presented their ongoing developments as well as opportunities for joint research activities in the context of ELI and HiPER.

From Laserlab-Europe, the scientific highlights of four Joint Research Activities (JRAs) – ALADIN, HAPPIE, LAPTECH and SFINX – were presented as well as potential issues and solutions. All agreed that the relationships between Laserlab-Europe JRAs and ELI and HiPER should be strengthened and that part of the JRAs should focus on ELI and HiPER bottlenecks as far as these are common basic issues and not purely mission-specific developments.

On the second day, the workshop discussions revolved around human resources, mobility and training. Roberta Ramponi from the European Technology Platform Photonics21 emphasised that there will be a shortage in the photonics workforce in the near future as the number of students in the field is too small. Efforts should focus on primary and secondary school education by training teachers in photonics. While both ELI and Laserlab-Europe have or plan training programs focused on the user needs, a stronger emphasis should be placed on increasing the basis of human resources, e.g. by joint preparation of Marie Curie Training Networks. One of the outcomes of this workshop was an agreement between Photonics21, the European Optical Society EOS, HiPER, ELI and LASERLAB-EUROPE to form a joint task-force on tackling these issues.

Sinéad Kennedy

LIFE in the USA

A letter from Mike Dunne

I am grateful for this opportunity to write a column for Laserlab Forum to provide a perspective following my move from the UK to the US. The past 6 months have been a time of great change and opportunity for the future.

As many of you may know, I left the CLF in June to take up the position of Program Director for Fusion Energy at the Lawrence Livermore National Laboratory in California. Or, more simply, my job is to run LIFE, which I found hard to resist!

LIFE (Laser Inertial Fusion Energy) is the program designed to take the anticipated demonstration of energy gain on the National Ignition Facility, and translate it into an operating power plant. Experiments on the NIF are in full swing, with the first integrated target shot just a few weeks ago, so it's an incredibly exciting time to be here. The atmosphere reflects the fact that this is the culmination of over 50 years of development and a few billion dollars of investment. The sociology of how people are responding to this event is fascinating to behold.

But it was with extremely mixed feelings that I left Europe. The CLF is a truly wonderful place to work, with a great staff, superb facilities and a very active user community. I wish them every success with the start of Gemini and Ultra operations, the development of the Vulcan 10 Petawatt project, and new ventures into diode pumped lasers and bio-imaging systems.

For HiPER, these are decisive times. Having nurtured the project from birth and through its initial steps, I see the strong opinions it engenders as healthy and creative. It has been a productive journey to date, providing essential pan-European focus for a long-standing goal. The potential impact of the project demands intense scrutiny and passion, and its technical challenges require close international coordination. To ensure success it is very important to look beyond the bounds of our short-term domestic pressures and keep focused on the end goal.

Along these lines, I undertook my transition to LIFE to help increase the pace of delivery for laser fusion, and ensure that US efforts have the greatest possible benefit on the world stage. I look forward to continuing to work with many of you to this end.

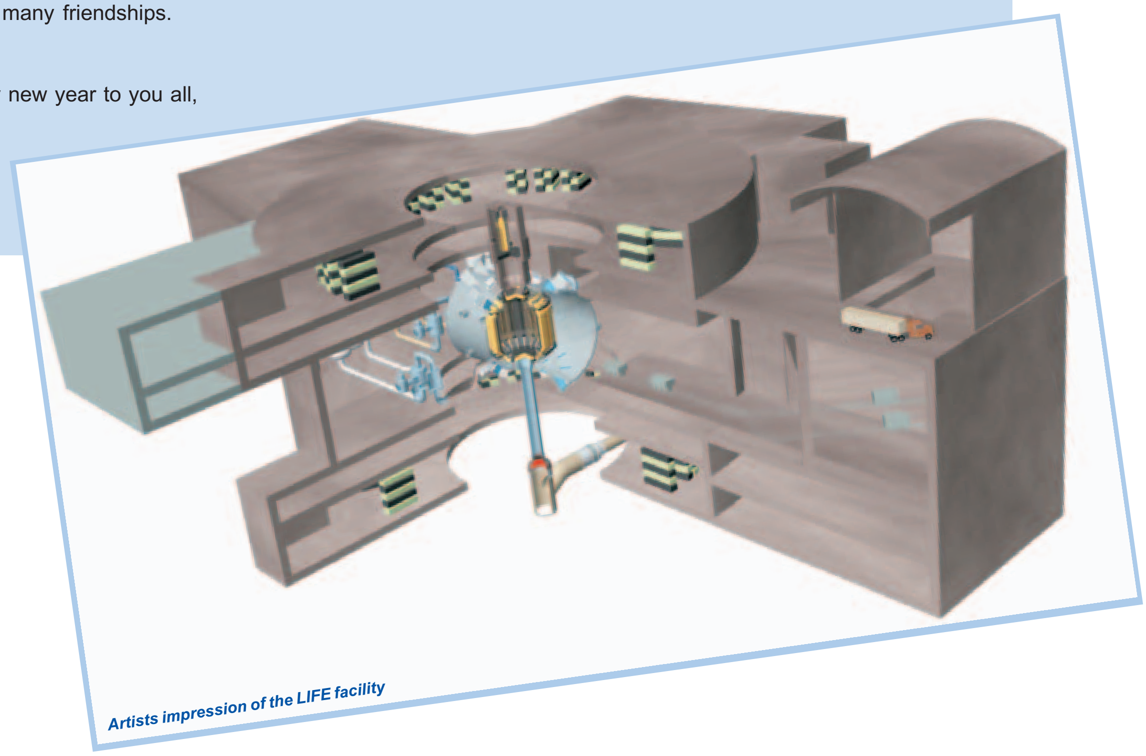
Looking from the US, it is very impressive to see the successful transition of ELI from its preparatory phase into delivery. The opportunity to provide Europe with an enduring, world leading capability will have impact far beyond our community. This success is testament to the importance of strong national leadership in an international context.

Last but not least, I turn to the community atmosphere and common cause embodied in the Laserlab-Europe family. I'm sure you are aware that this is quite unique, not found anywhere else in the world. I use the example regularly over here to demonstrate what can be done if there is a shared will. Long may this thrive.

So - I look forward to returning many times to see the active development of laser science in Europe. I wish you all every success, and hope you will find the time to visit the "wild west" to remind me of my roots and to continue our many friendships.

A very happy new year to you all,

Mike.



Artists impression of the LIFE facility

Erasmus Mundus

In 2004, the European Commission established the Erasmus Mundus programme, initiating the establishment of European joint master courses intended for both European and non-European students and teachers. LASERLAB-EUROPE takes part in two of these master courses, OPSCITECH and EUROPHOTONICS. The latter programme also includes a doctorate programme.

European Commission
ERASMUS MUNDUS

Erasmus Mundus is an extension of the highly successful Erasmus programme, which has offered millions of EU students and teachers the opportunity to spend part of their university education in a different EU country since the 1980's. The Erasmus Mundus Masters Courses are integrated courses offered by a consortium of at least three universities in at least three European countries. Students follow courses in at least two of the participating universities, generally one year in each city, in order to obtain a recognised double or joint diploma. To stimulate students from third countries, both from within and outside the EU, to enter the master courses, Erasmus Mundus offers a special scholarship scheme.

OPSCITECH

The Erasmus Mundus masters course Optics in Science & Technology (OPSCITECH) is offered by five universities, among which Friedrich Schiller University in Jena (full partner of LASERLAB-EUROPE) and associate partner Imperial College, London. The other universities involved are in Delft, Paris and Warsaw.

The masters programme is divided into core education, provided at all sites (fundamentals of optics, but also so-called transferable skills such as management, entrepreneurship, and languages), and advanced courses that are more specific to locations. Advanced courses are provided in image science and analysis, lasers, optical systems, optomechatronics, optical metrology, nano-optics, quantum and atomic optics.

Starting in 2007, around 20 non-European students a year have been given a scholarship for the OPSCITECH programme, with a maximum of three students from the same country. Students originate from China, India and Pakistan, but also from the Americas and Eastern Europe. From 2010, EU-students can also apply for a scholarship.

Students choose one of the five sites for their first year, and one of the remaining four sites for the second year. In addition, the students participate in two summer workshops organised in turn by each partner university. During these workshops, graduating students present their masters thesis, and seminars are given by scholars and professionals.

After completion of the OPSCITECH course, the students are awarded degrees of both host institutions involved in their study path.

EUROPHOTONICS

LASERLAB-EUROPE partner ICFO (Barcelona) participates, together with three universities in the Barcelona area, in the EUROPHOTONICS master programme, which started this year. In the doctorate phase, ICFO is joined by our partner LENS (Florence). For a period of five years, the programme has funding for twenty masters students and ten PhD students a year.

The EUROPHONICS master course is coordinated from Marseille, which is also where students will follow the first semester. After a second semester in Karlsruhe, students can choose whether they want to spend the third semester in Barcelona, Marseille or Karlsruhe.

The EUROPHOTONICS master course focuses on advanced research and applied topics in photonics engineering, biophotonics, and nanophotonics. Students who completed the course will have acquired the knowledge and skills to play a role in developing new imaging tools for biological processes, possibly leading to clinical applications. They also learn to understand and manipulate optical processes at the nanometer scale, and will be able to find their way into the nanotechnology industry.

In addition to the master course, EUROPHOTONICS offers a three-year PhD track, which can also be followed separately. The topics addressed are the same as in the master course. Both LENS and ICFO are involved, together with research institutes in Karlsruhe, Marseille and Barcelona. The PhD candidate will work in and be supervised from two of the cities involved, thereby benefiting from complementary expertise provided by the partners.

In both the master and PhD tracks, about sixty percent of the participants is from outside Europe. Thus, an international mix of students is created, which will likely stimulate future cooperation in laser science across the world.

http://www.europhotonics.org/wordpress/
http://www.master-optics.eu

Marie Curie Initial Training Networks and LASERLAB-EUROPE

Within the structure of the FP7 Marie Curie Actions, the European Commission is funding so-called Initial Training Networks (ITN), which facilitate specialized training modules and networking activities on a transnational scale. The networks support on the one hand recruitment of young researchers such as PhD students and postdocs, and on the other hand recruitment of experienced 'visiting' researchers who can contribute to knowledge transfer. In both cases, researchers are normally required to cross national borders – in the spirit of the Marie Curie Actions.

LASERLAB-EUROPE participates in four Marie Curie Initial Training Networks, two of which are coordinated by our partners: The ATTOFEL network (Ultrafast Dynamics using Attosecond and XUV Free Electron Laser Sources) is led by Prof. Marc Vrakking from MBI, and the HARVEST ITN (Control of Light Use Efficiency in Plant and Algae) is coordinated by Dr. Jan Dekker of LaserLaB Amsterdam (the former LCVU). In addition, LASERLAB-EUROPE participates in ICONIC (Imaging and Control in Chemistry) and, from 2011, in the CORINF network (Correlated Multielectron Dynamics in Intense Light Fields).

CORINF: laying the ground for dynamic imaging

Starting in 2011, the Marie Curie Initial Training Network 'Correlated Multielectron Dynamics in Intense Light Fields' (CORINF) will join the efforts to establish a solid theoretical basis for dynamic imaging of molecular processes with ultrashort laser pulses. Dr. Olga Smirnova represents LASERLAB partner MBI in this European network. She explains what CORINF is all about.

Imaging structures and dynamics of different systems, from isolated molecules to clusters to condensed phase, is a major direction of modern science. Its current frontier is dynamic imaging, which will combine sub-femtosecond temporal and angstrom-scale spatial resolution. This direction is driven by the revolutionary achievements in laser technology. European science in general and LASERLAB-EUROPE in particular are making major investment in such technologies, ranging from infrared to XUV/X-ray and from table-top to XFEL. The technological advances have created urgent demand for new theoretical methods. Without major advances in theoretical methods and the corresponding training of young researchers working in the area of intense light-matter interaction at ultrafast timescales, the dream of attosecond dynamic imaging will not be realized. Filling this gap is the goal of the Marie Curie training network CORINF.

High peak intensity and short pulse duration are the key characteristics required for both X-ray/XUV and IR imaging. They are also the hallmark of the new generation of European light sources both in X-ray/XUV and IR range (FLASH, XFEL, ELI). For X-ray imaging, high intensity is needed to obtain appreciable signal from individual molecules. For IR imaging, high intensity provides a route to combining sub-angstrom spatial and attosecond temporal resolution. In both cases, intense fields inevitably excite complex dynamics. The success of imaging techniques depends on our understanding of these largely unknown dynamics, creating demand for the theory of complex systems in intense fields. Such theory is the research focus of the CORINF network.

The CORINF network will provide training and research in the theoretical foundations in attosecond science and in the physics of intense light-matter interaction. One of the natural components of the network activity will be the development of strong links between theory and experiment, including active interaction with the experiment-driven ATTOFEL Marie Curie training network. R&D objectives of this network include the development of a flexible Numerical Platform (NPCORINF) for modelling intense-field multi-electron dynamics. NPCORINF will be a set of software packages addressed to the general scientific community and manageable by non-expert theoretical or experimental teams.

The research will proceed in the three inter-related directions:

- Small Polyatomic Molecules in Intense Light Fields, IR and XUV/X-ray
- Macromolecules and Clusters in Intense Light Fields, IR and XUV/X-ray
- Numerical Platform (NPCORINF).

Specific problems that will be addressed are: (i) the inherently many-electron aspects of intense field ionization in molecules and clusters; (ii) electron-molecule scattering in strong IR fields; (iii) the role of highly excited and autoionizing states in molecules during and/or after application of intense XUV/IR pulses; (iv) mechanisms of correlated energy absorption in single and multi-component clusters; (v) electronic decay & relaxation processes in clusters at different ionization stages. These problems are the key steps towards dynamic imaging of individual molecules, with the potential of combining attosecond temporal and sub-angstrom spatial resolution.

Olga Smirnova

Quantum state storage in nuclear spin states using an Atomic Frequency Comb

Quantum information may provide tools to fundamentally change what is practically possible within the area of information science and technology. Recently, the Applied Physics group at Geneva University proposed to use a so-called Atomic Frequency Comb to create a quantum memory. As part of the Transnational Access Programme, they collaborated with the group of Prof. Stefan Kröll in Lund to realize a quantum memory in a Pr doped crystal.

Today few commercial devices are based on the non-classical laws of quantum mechanical systems, but equipment for quantum cryptography (quantum key distribution), which as a minimum non-classical resource requires quantum superposition, is presently available from commercial suppliers. Long distance quantum key distribution, however, will require additional resources in the form of *quantum repeaters*. A quantum repeater makes extensive use of non-classical resources and operations such as entanglement and quantum teleportation. A key component in a future quantum repeater is a quantum memory.

Quantum memory development has been exceptionally rapid during the last very few years. Lately, a substantial part of the most successful quantum memory developments has been achieved using rare-earth-ion doped crystals kept at cryogenic temperatures. Recent results include conditional fidelities of 97%, efficiencies of 70% and storage of >100 pulses, all of theses are properties essential for current quantum repeater architectures. The remaining important characteristic to experimentally demonstrate is the storage time. By storage in long-lived spin states, storage times of the order of seconds and longer become possible.

For quantum state storage in rare-earth-ion doped crystals the optical input state is typically distributed across an ensemble of billions of ions. When such a material is used for storing a weak coherent state, containing an energy corresponding to just a few photons, the excited state probability amplitude for each ion is exceedingly low. But the stored state can still be faithfully recalled by arranging the experiment such that the electro-magnetic probability amplitudes from all the billions of superposition states become in phase at the time when the stored state is to be emitted. This utilizes so called echo or coherent rephasing techniques, which is the key mechanism in Nuclear Magnetic Resonance, Electron Spin Resonance as well as optical photon echoes.

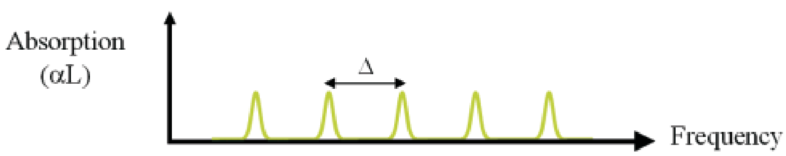


Fig. 1: An Atomic Frequency Comb is an absorbing frequency structure consisting of a set of identical equidistant absorption peaks (α is the absorption coefficient and L is the length of the absorbing sample). The structure looks like an optical frequency comb (or a laser mode structure). If the atoms in a frequency comb where the peaks are separated in frequency by an amount Δ are simultaneously put in superposition states, the Atomic Frequency Comb will emit a train of pulses that are separated in time by 1/Δ. However, the Atomic Frequency Comb (AFC) can be created such that all energy stored in the AFC structure is emitted in the first pulse.

A complication for quantum state storage in comparison with the conventional applications utilizing coherent rephasing techniques is that the output signal energy preferably should be as large as the input signal energy, i.e. the efficiency, (energy of the storage pulse) / (energy of the recalled pulse), should be unity. Various schemes have been developed to approach this limit. In classical storage inverted gain media can be used to boost the efficiency, but for quantum state storage gain destroys the fidelity. To approach unity efficiency in quantum state storage a first requirement is that the absorption should be sufficiently large so that the input pulse is completely absorbed. A second criterion is that there should be no dissipation or decoherence during the storage time and a last criterion is, as briefly described above, that the phases of all ions should be aligned such that the sample coherently emits the energy that has been stored.

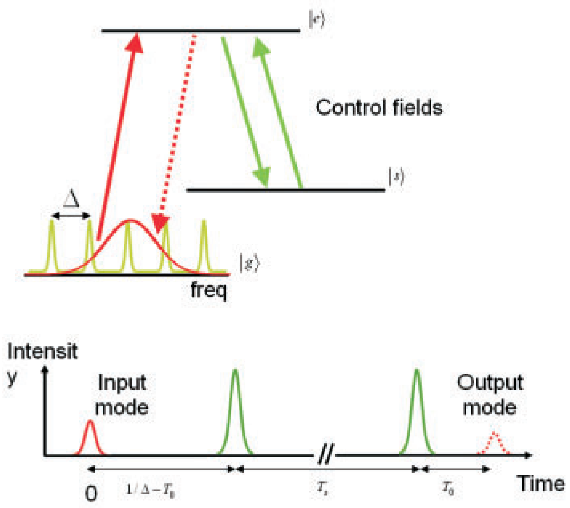


Fig 2: The energy level diagram shows a ground state, |g>, with an AFC structure. The spectrum of the input pulse, in red, and its spectral overlap with the AFC structure is also shown. In the intensity versus time plot below shows the input pulse at time t=0. An output pulse would occur at time t=1/Δ. However before that, at time t= 1/Δ -T_0, a pulse resonant with the |e> → |s> transition with pulse area π (a π-pulse) transfers the probability amplitude from the excited state |e> to the spin state →|s>. After a storage time T_s in the spin state a second π-pulse transfers the probability amplitude back to the excited state and the memory outputs the stored state after an additional time T_0.

A general obstacle has been to have sufficient numbers of absorbing ions to ensure that the incoming light pulse is absorbed, while still fulfilling the other two criteria. The Group of Applied physics at Geneva University (Mikael Afzelius, Christoph Simon, Hugues de Riedmatten and Nicolas Gisin) recently presented an innovative idea for solving this problem; namely to create a so-called Atomic Frequency Comb (AFC). An Atomic Frequency Comb is an absorbing comb-like structure in frequency space, see Fig. 1. This approach has made it possible to use a larger number of ions for the memory construction than previous techniques, further it has made it possible to store long sequences of 100 pulses or more, which is essential for constructing a useable quantum repeater.

A pulse impinging on an AFC structure where the absorbing peaks are separated by frequency Δ will automatically reemit the pulse after a time $1/\Delta$. In the limit of high absorption and narrow peaks, all the stored energy is emitted at this time giving unity storage efficiency. However, automatic recall at time $1/\Delta$ is not very useful, one needs recall on demand. This could be achieved by, as shown in Fig 2, applying a π-pulse after the storage pulse transferring the probability amplitude from the excited state to another state. In this case a lower lying nuclear spin state, |s>. To recall the pulse the probability amplitude is transferred back from the spin state, |s>, to the excited state, |e>, leading to emission of the stored information pulse.

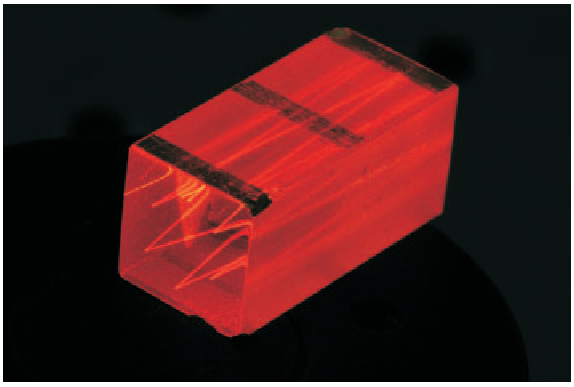


Fig 4: Picture of the storage material, a Pr doped Y_2SiO_5 crystal. The end faces of the crystal are reflection coated except for two wedge shaped areas which are anti-reflection coated. In this picture a laser beam enters at the anti-reflection coated wedge and bounces back and forth on the high reflectance areas until it eventually gets back to the anti-reflection coated part and exits. The beam path in the crystal can be clearly seen because of the Pr ion fluorescence. In the current experiment however only a single path through the crystal was required to get sufficient absorption. (Photo: Tomas Svensson)

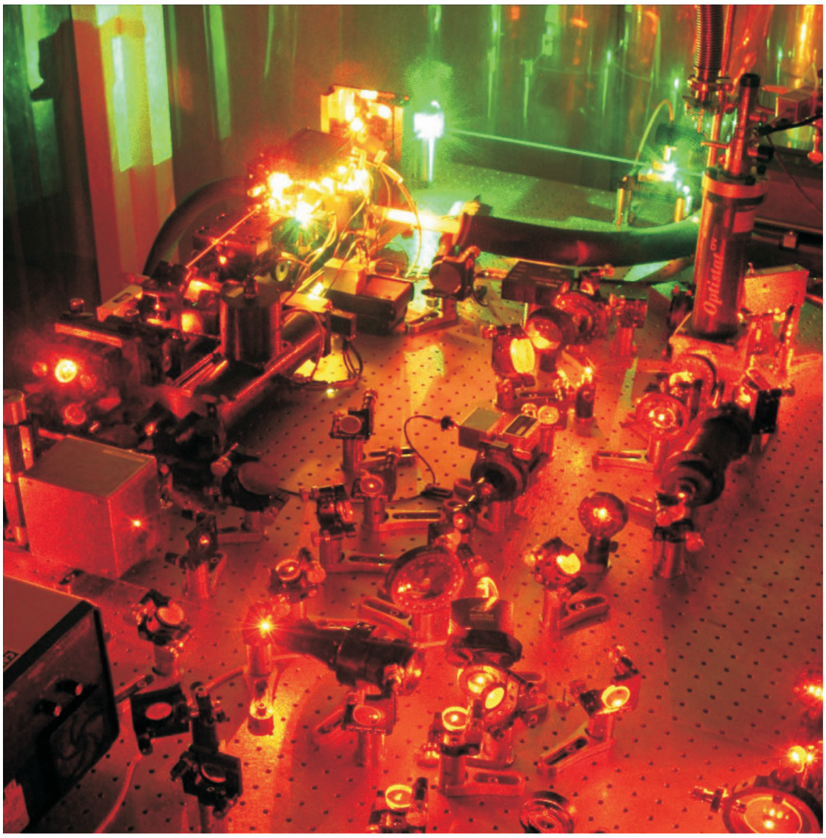


Fig 3: Dye laser system frequency stabilized to a line width of 1 kHz. Instead of being locked to a cavity the laser is frequency stabilized against a spectral hole in a Pr doped Y_2SiO_5 crystal. (Photo: Tomas Svensson)

A suitable system for testing the concept above is Pr doped inorganic crystals. Carrying out such experiments requires a sub 100 kHz line width laser at 605 nm, extensive optical pulse control capabilities and liquid helium cryogenics. At Lund Laser Centre all these things are available and the group at LLC also has considerable experience from related experiments in Pr doped yttrium silicate crystals.

It was decided that the Geneva group would first visit one week in order to test pulse sequences for creating suitable AFC structures. These results could then be analysed and the sequences could be refined before a second two week visit for the actual quantum state storage experiments.

Using the 1 kHz line width dye laser system at LLC (Fig. 3) and the extensive pulse control system developed at the LLC laboratory it was possible, using sequences of up to several hundreds or sometimes thousand pulses, to prepare high quality AFC structures (peak separation, $\Delta \approx 1.2$ MHz (compare Fig. 1), line widths, $\Gamma \approx 150$ kHz and a transmission at the peaks of only $e^{-\alpha L} = e^{-8} \approx 0.0003$) in a Pr doped crystal (Fig. 4) and at their second visit the Geneva group was indeed able to perform a sequence of successful experiment demonstrating spin storage with on demand recall and storage of multiple (2) modes.

The success of this spin storage experiment has since raised considerable interest and the resulting PRL publication has also been selected as the Editor's Choice in Science.

Stefan Kröll

M. Afzelius, I. Usmani, A. Amari, B. Lauritzen, A. Walther, C. Simon, N. Sangouard, J. Minár, H. de Riedmatten, N. Gisin, S. Kröll, "Demonstration of atomic frequency comb memory for light with spin-wave storage", Phys Rev Lett 104, 040503, 2010

HiPER Outreach

HiPER has recently participated in several important outreach activities. On 21st - 24th October 2010, representatives of the project presented at the Florence Creativity Festival where the project attracted significant interest, including that of the Mayor and local government officials. And on 3rd - 4th November the project was one of the main attractions at the Photonex industry exhibition where project members engaged with laser, diode and optics suppliers. In addition, the project team took part in the discussion forum and presented two of the invited talks.

Anne-Marie Clarke

ELI getting real: from inception to implementation

Started in November 2007, the preparatory phase of ELI, the Extreme Light Infrastructure, will come to its conclusion at the end of 2010. While members of the various working groups are finalizing the very last deliverables, the host countries are getting ready to take over for the implementation phase. They will do so on solid grounds, thanks to the results of three years of intense efforts from all partners. By turning a concept into what will soon become a reality, the ELI-PP has fully accomplished its mission. This collective achievement is worth celebrating: it embodies the maturity and ambition of the European laser community as well as its ability to team up for an exceptional project. Therefore, on 10 December 2010 in a dedicated event – "ELI getting real: from inception to implementation" – hosted by the Czech Embassy in Paris, the ELI Delivery Consortium officially takes over the lead of the project from ELI Preparatory Phase, thereby announcing the imminent launch of ELI's implementation. The three pillars are in the meantime preparing the next steps to be done: In the Czech republic, final approval of the funding application is expected from Brussels soon, with a signature on the grant agreement by the end of the year. In Hungary, the scientific case of ELI-ALPS has been completed and will be discussed with international experts and reviewed by the ELI Scientific Advisory Committee. Romania is now just waiting for the official green light before starting construction. People are submitting proposals for new directions of investigation that can be followed when ELI-NP becomes operational.

Patrizio Antici

Announcements

Forthcoming events

20-21 January 2011, First General Meeting of NCPs, Lisbon, Portugal

4-7 July 2011, Laserlab Europe User Community Training: Regional Eastern Europe Training School for Potential Users joined with Workshop on Advanced Optical Techniques in Bio-Imaging, Bratislava, Slovakia

July 2011, HAPPIE Meeting, Bucharest, Romania

How to apply for access

Interested researchers are invited to contact the LASERLAB-EUROPE website at www.laserlab-europe.eu/transnational-access, where they find all relevant information about the participating facilities and local contact points as well as details about the submission procedure. Applicants are encouraged to contact any of the facilities directly to obtain additional information and assistance in preparing a proposal.

Proposal submission is done fully electronically, using the LASERLAB-EUROPE Electronic Proposal Management System. Your proposal should contain a brief description of the scientific background and rationale of your project, of its objectives and of the added value of the expected results as well as the experimental set-up, methods and diagnostics that will be used.

Incoming proposals will be examined by the infrastructure you have indicated as host institution for formal compliance with the EU regulations, and then forwarded to the Users Selection Panel (USP) of LASERLAB-EUROPE. The USP sends the proposal to external referees, who will judge the scientific content of the project and report their judgement to the Users Selection Panel. The Users Selection Panel will then make a final decision. In case the proposal is accepted the host institution will instruct the applicant about the further procedure.

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