Issue 13 | May 2012

Laserlab Forum

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

Joint Research Activities: Final Results

Multipass amplifier based on thin disk laser technology developed at MBI within JRA HAPPIE © Robert Jung

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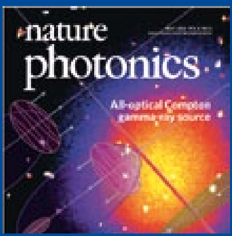

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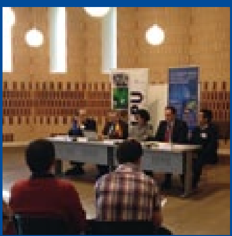

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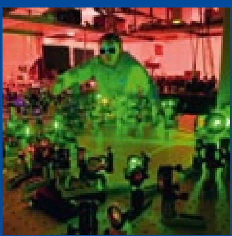

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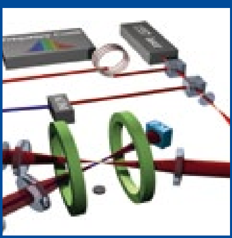

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Editorial

Tom Jeltes

Time flies. This is already the last issue of Laserlab Forum reporting on LASERLAB-EUROPE II. But there is no reason to mourn. Its successor LASERLAB-EUROPE III, which will run till 2015, has already ceremonially kicked off on March 15 in Bratislava, Slovakia. The next phase of LASERLAB-EUROPE had its official start in the presence of Project Officer Hugues Crutzen of the European Commission and high representatives of the Slovak government and the Slovak Academy of Sciences.

At the start of LASERLAB II in 2009, a significant number of new partners from the new Member States of the European Union joined the consortium, pulling the centre of mass of LASERLAB eastwards.

The International Laser Centre, local host of this year's Kick-off and General Assembly Meetings, is exemplary for the growing impact of the new partners. It plays a key role as national contact point and as coordinator of LASERLAB-EUROPE's training activities. As LASERLAB coordinator Prof. Wolfgang Sandner has indicated, Bratislava was deliberately chosen for this important event, stressing that lasers and photonics, one of the five key technologies of the European Union, are not only essential for the scientific, but also for the socio-economic future of any country. More about the history and strengths of the ILC can be found on page 4 of this issue of Laserlab Forum.

Another sign that the new Member States are up-and-coming, is the fact that the world's most powerful scientific lasers, forming the European "Extreme Light Infrastructure" ELI, are presently being established in three sites in the Czech Republic, Hungary, and Romania. At the meeting in Bratislava, keynote addresses were given by the ELI plenipotentiaries representing each of these new Member States. As usual, on the back page of this issue the latest news can be found on ELI as well as on that other civilian European mega-project, HiPER – which investigates the possibility of laser-driven fusion as a clean and practically inexhaustible source of energy for mankind.

LASERLAB-EUROPE III will comprise 28 of the largest European laser infrastructures and, together with subcontractors and associate partners, will cover 19 European countries. The LASERLAB formula, providing free access to its facilities for a large number of researchers from European universities, can be considered a huge success – inspiring Latin American scientists and governments to set up similar collaborations and to seek contact with their European peers. More about the LatinLaserLab meeting that was recently held in this context can be read on page 5.

The end of LASERLAB II also marks the conclusion of the five Joint Research Activities. A final roundup, showing the highlights of each JRA, could not be absent from this issue. Enjoy reading and see you in LASERLAB-EUROPE III.

Tom Jeltes

News

ERC Advanced Grant for 2DUV spectroscopy

Giulio Cerullo, professor at the Politecnico di Milano, has received an ERC Advanced Grant of 2.5 million euro. The grant will allow him to develop a method to study DNA and proteins using ultrashort ultraviolet laser pulses.

Prof. Giulio Cerullo

The proposed technique, 2DUV spectroscopy, can be seen as an extrapolation of the well-established 2D Nuclear Magnetic Resonance technique, which has been a great help to structural biology as it allows to resolve complex molecular structures with high spatial resolution. Using IR and visible laser light, 2D spectroscopy has already had a large impact on our understanding of the structure of peptides and proteins, as well as the mechanisms of energy relaxation in photosynthetic complexes and semiconductors.

As many biomolecules such as DNA and proteins display strong electronic absorption in the ultraviolet, extension of the 2D technique into the UV range might yield a wealth of information on these important molecules. However, technical difficulties already significant in the visible range become even more challenging in the UV range. Cerullo's project aims at overcoming these problems and establishing 2DUV spectroscopy as a routine experimental tool. The theoretical support necessary to interpret the 2D data will be provided by co-investigator Dr. Marco Garavelli, computational photochemist at Bologna University (Italy).

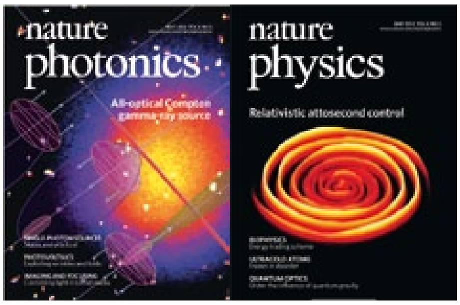
Cerullo plans to apply 2DUV spectroscopy to both DNA and proteins. In DNA, a surprisingly small fraction of the absorbed UV photons lead to damage of the molecular structure of the DNA strands, and hence to changes in our genetic information. This is due to a built-in safety mechanism that relies on rapid conversion of electronic energy to vibrational energy. 2DUV spectroscopy has the potential to shed more light onto this mechanism, enabling us to understand how nature is able to avoid potentially life-threatening DNA damage.

Another planned application of the new technique is to study the folding properties of proteins – an important topic as diseases such as Alzheimer's, Parkinson's and type II diabetes are connected to misfolding of the peptide chains that make up proteins.

LOA teams produce x-ray and ultraviolet radiation with lasers and plasmas

Two experiments of our French partner LOA and collaborators, on the production of energetic X-ray radiation and plasma-generated attosecond XUV-pulses, have led to recent online publications in top magazines Nature Photonics and Nature Physics, respectively.

In the first experiment, researchers from the FLEX and SPL teams at LOA have demonstrated a new method based on laser-matter interaction to produce beams of energetic x-ray radiation with unique properties. The physical process used here is called inverse Compton scattering, during which a beam of energetic electrons collides with a laser. Using an all-optical technique, LOA researchers successfully produced flashes of gamma-ray radiation more than 10,000 times brighter than those produced by existing conventional sources. Compact, simple and efficient, the scheme is only based on the interaction between an intense femtosecond laser and a helium gas jet.



All-optical Compton gamma-ray source, Nature Photonics (online - April 22, 2012);

Attosecond control of collective electron motion in plasmas, Nature Physics (online - March 25, 2012)

In the second experiment, the PCO team led by the Laboratory of Applied Optics, in collaboration with CEA-Saclay and the Laboratory for the Use of Intense Lasers, succeeded for the first time to accelerate and guide electrons in a controlled manner in a plasma using a laser. These electrons excite the plasma, which then emits electromagnetic pulses at ultrashort wavelengths in the extreme ultraviolet range. The resulting attosecond radiation energy can be used to probe the ultrafast electronic processes.

European shock ignition experiments: progress towards nuclear fusion

Shock ignition has recently been selected by the HiPER project as the mainstream approach for ignition of thermonuclear targets by laser beams. Recently, two first sets of experiments in an European context have been realized at LULI (Palaiseau, France) and at the PALS laser in Prague.

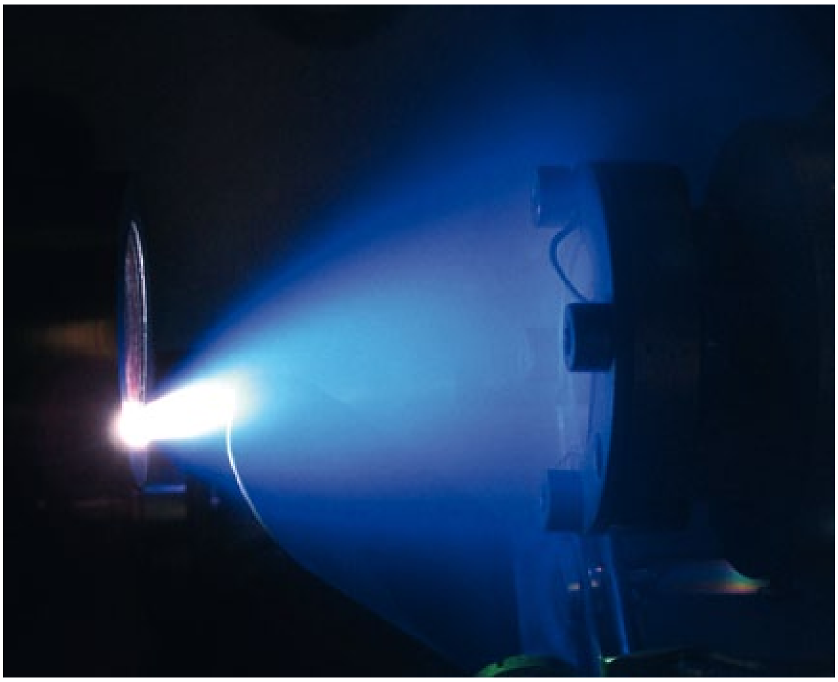
In shock ignition (SI), a pellet of nuclear fuel is compressed and heated so much by a shock wave that a fusion reaction is started. For this to happen, pressures of the order of 300 Mbar are needed. The big advantage of the SI approach is that it is basically compatible with present-day laser technology. Therefore a proof-of-principle of SI could be realized within the next decade on LMJ (Laser Mégajoule, being built near Bordeaux, France), taking advantage of the academic access granted by the French nuclear science directorate CEA to the French and European academic community (up to 30% of laser shots).

The PALS experiments, performed within the LASERLAB framework, have been conducted by a large team including researchers from CELIA Bordeaux, IPPLM Warsaw, CNR Pise, Univ of Rome "Tor Vergata" and of course PALS researchers and technicians. Both the PALS and LULI experiments were dedicated to study laser-matter interaction and shock generation using planar targets, which is not a realistic configuration for SI, but does allow for a much easier access to diagnostics and thus allows studying the physics in much more detail.

At LULI the laser intensity was 10^{15} W/cm^2 and the long laser pulse (up to 2 ns) allowed maintaining the shock pressure during shock propagation in the target. At PALS, higher intensities were reached (up to 10^{16} W/cm^2) but due to the shorter pulse duration (300 ps) could not be maintained in time. The PALS experiment provided evidence for the generation of hot electrons at energies of the order of 50 keV. In both cases, the amount of light back reflected due to parametric instabilities appears to be quite low, which could be good news for SI.

International Laser Centre, Bratislava

On March 15-16, the combined Kick-off and General Assembly Meetings of the third phase of LASERLAB-EUROPE took place in Bratislava, Slovakia. The event was hosted by the International Laser Centre (ILC). The Slovakian research centre is one of the institutes from new Member States that joined the consortium at the start of LASERLAB-EUROPE II in 2009. Time for a closer look.



Pulsed laser deposition of thin films.

The International Laser Centre in Bratislava was established by the Ministry of Education of the Slovak Republic in January 1997 with the aim to build a joint research platform of excellence in photonics and laser technologies in Slovakia. ILC was founded as an independent institution and is located in the area of the Slovak University of Technology and Comenius University in Bratislava.

Originally, the ILC was launched as an inter-governmental project aimed at the development of advanced experimental infrastructure, allowing to foster collaborative research and applications in industry and health care. The project was based on the contract between ILC in Bratislava and the International Laser Center of Moscow State University (MSU).

In the years 1997-2007, the ILC was funded with equipment in the equivalent of 18 million USD from the resources related to the debt of the Russian Federation towards the Slovak Republic. As a result, a set of unique research labs was created spanning from ultrafast spectroscopy, material analysis, information technology to nano- and bio-medical sciences.

In 2007 ILC reached the steady-state operation with 23 employees. It is now composed of two departments – the Department of Laser Technologies and the Department of Biophotonics. The structure of ILC is completed by joint external laboratories at nearby institutions. ILC thus provides a wide inter-disciplinary infrastructure for basic and applied research and development in many fields of laser-based and photonic technologies, available for researchers throughout Slovakia.

The third phase of the ILC development is taking place since 2008 and can be characterized by an effort to integrate ILC into the existing European scientific structures. Several EU funded projects, aimed at the integration and the support of research teams operating in the field of nanotechnologies, molecular electronics and biophotonics, helped ILC to develop the technical infrastructure for the creation and diagnostics of nanostructures and nanomaterials, components for molecular electronics and integrated photonics devices.

Another important achievement is the establishment of the Laboratory of Ultrafast Laser Photonics (LULPH) at the beginning of 2012. The LULPH is a joint laboratory between ILC, Comenius University and the Slovak Academy of Sciences which targets the areas of ultrafast time-resolved chemistry, high-field THz science and laser-plasma interaction in the strong-field regime.

In addition to the local environment, research and teaching activities at ILC are closely related to international organizations and projects, such as LASERLAB-EUROPE. To foster a wide collaboration by providing experiments in European research centres, ILC entered the LASERLAB-EUROPE network in 2009. Our main tasks in LASERLAB were to develop a setup for multi-spectral fluorescence lifetime imaging microscopy with non-linear excitation within the OPTBIO JRA, and to manage the user community training activities. Hosting the LASERLAB III Kick-off and General Assembly meetings in Bratislava was a great opportunity for ILC to present our achievements to our partners and stregthten the social and scientific contacts within the LASERLAB consortium.

Dusan Chorvat and Ljuba Bacharova
http://www.ilc.sk/en/

White-light continuum generated by a high-power femtosecond laser.

Latin LaserLab: A bridge of light between Latin America and Europe

Research with short and intense lasers is an international enterprise which requires collaboration with researchers around the world. This collaboration is essential for advancing our field; for this reason, LASERLAB-EUROPE establishes relations with different regions around the world.

In order to create links with researchers from Latin America, the second LatinLaserLab (L^3) meeting took place on 5-6 March 2012 in Salamanca, Spain, hosted by the Centro de Laseres Pulsados (CLPU). The objectives of the meeting were to introduce the activities of LASERLAB-EUROPE and the different national networks in Latin America, looking for a common ground for future scientific and technical collaborations.

The success of the European ultrafast and high-power communities like LASERLAB-EUROPE has inspired groups of researchers around the globe to establish laser facilities to boost their research in a wide range of areas ranging from basic science to technology and applications. Currently, several Latin American countries are building national networks to establish laser facilities to serve their country's research groups.

In this second L^3, three Latin American networks participated together with several European scientists. Argentina, represented by the Optical Research Center (CIOP) in La Plata, has installed a GW fs laser at CIOP which will be used as a facility for several groups within Argentina; Mexico, represented by the Universidad Autonoma de Mexico (UAM) has built a network composed of six national groups, all working in femtosecond laser research. These groups have applied for funds to their national finance agency to establish a femtosecond laser facility in Mexico. The meeting also had a representative from the University of Pernambuco in Brazil, which belongs to the National Institute of Photonics, a virtual institute with groups from all over Brazil involved in ultrafast and ultrashort laser pulses.

The Spanish Center of Pulsed Lasers (CLPU), being close to both the European and Latin American scientists, wants to become the bridge between Latin America and Europe by hosting events like LatinLaserLab. During the meeting we have identified several opportunities for collaboration both in the short and in the long term. The proposed lines of collaboration can be divided into three main categories.

The first line of collaboration is about establishing channels of communication between the communities, allowing rapid identification of common interests and opportunities for scientist and technology makers on both sides of the Atlantic. The second line is about education and opportunities to train Latin American students in the near future, creating a pool of trained scientists for the new laser facilities opening in Europe during the next few years. Finally, there are the scientific collaborations among groups of the Latin American networks and their European counterparts – the main interest expressed by all participants.

Apart from these long-term opportunities for collaboration, there are immediate actions to follow as identified in the conclusions of the meeting: All three Latin American countries present at the second L^3 will explore the Access formula and have shown interest to access the user programme of LASERLAB-EUROPE. Also, Latin American groups want to invite experts from the LASERLAB community for short visits to establish links between the two communities. Furthermore, an Ibero-American network by the name 'Thematic networks' will be established, an important action to achieve the LASERLAB objectives.

The LatinLaserLab (L^3) hopes to become an international network of scientists collaborating to advance ultrafast and ultra-intense laser research. As LASERLAB-EUROPE III will start shortly, now is time to make use of the opportunities that have been identified so far.

Finally, all participants of L^3 send a message to the LASERLAB community: ¡ Saludos y buena suerte !!!!

Camilo Ruiz and Yaiza Cortés (CLPU)
http://clpu.es/es/latin-laserlab-l3.html

Joint Research Activities: Final Results

As time is up for LASERLAB II, the Joint Research Activities of this second phase of LASERLAB-EUROPE have come to an end. In the past few years, five important topics in the field of laser science have been addressed by five collaborations of scientists from a large number of partners, each focussing on important developments in their fields of expertise. Creation of ultrashort and high-power laser pulses for nanofabrication and fundamental science, laser acceleration of charged particles, production of intense x-rays and application of lasers in biology and medicine: the following pages give an overview of the many steps forward that have been taken in the context of the Joint Research Activities LAPTECH, ALADIN, SFINX, OPTBIO and HAPPIE.

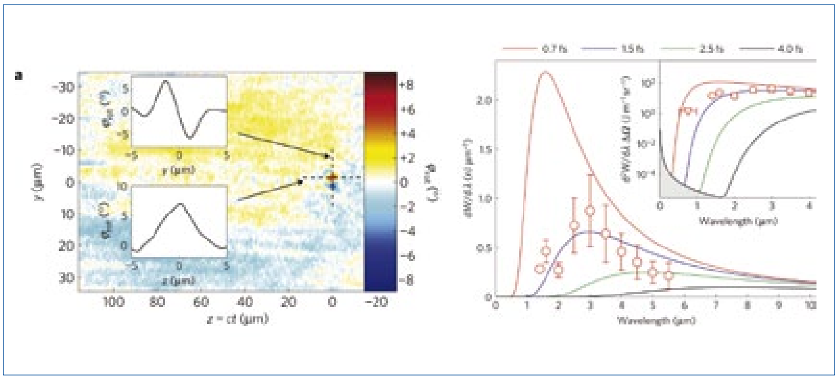


Fig. 1 : On the left :MPQ-Polarization rotation angle of the probe beam from [1].
On the right: LOA-Bunch length measurement from [2]

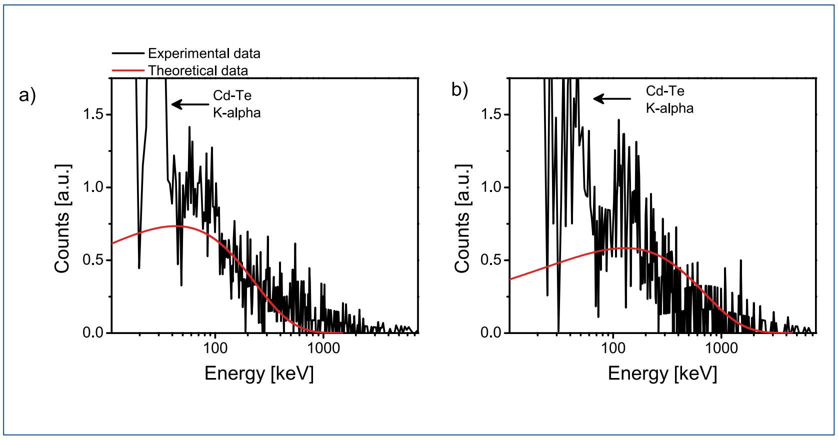


Fig. 2 : Single shot X ray spectra in the weakly resonant case (a) and in the strong resonant case (b), from [3]

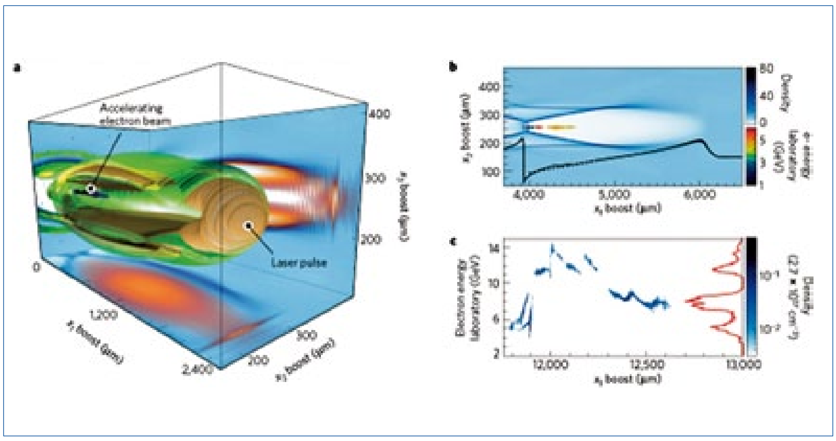


Fig. 3 : Boosted frame simulations with a 250 J laser. a) 3D view of the wakefield, b) 2D central slice of the plasma density, c) electron energy after the end of the plasma jet, from [4]

JRA LAPTECH: Laser Plasma Accelerators Technology

The laser plasma accelerators approach offers the possibility to produce in a compact and economical way high quality electron beams, of interest for example for time-resolved studies on unprecedented time scales. European scientists have contributed to pioneering developments and maintain leadership in this field, but competition from the US and Asia is growing rapidly. To meet these challenges, scientists from LASERLAB-EUROPE have taken the initiative to develop a Joint Research Activity with both theoretical and experimental tasks to investigate laser plasma accelerators.

Successful activities within the JRA LAPTECH have helped to define the landscape of laser plasma accelerators by providing the theoretical and experimental basis for the design of future accelerators capable of delivering high brightness, ultra-short high energy electron bunches, thus promoting a vast range of applications. LAPTECH was composed of 7 contractors, MPQ, IST, STRATH, LIRM (CEA), SLIC (CEA), LLC and LOA. To complete this JRA, two teams from Dusseldorf (HHUD) and Dresden (FZD), have participated as sub-contractors of MPQ.

A comprehensive experimental programme, closely coupled with the theoretical one, has allowed to investigate, to demonstrate, and to develop laser plasma accelerators. Among an impressive number of high impact results one can list the following results:

- At MPQ, real time electron acceleration was observed by using the Faraday rotation effect; electron bunch lengths in the few fs range were deduced from the experimental data (Fig.1 a).
- At LOA, using Coherent Transition Radiation, 1.5 fs- 4kA bunch length was measured in the colliding laser pulse scheme (Fig. 1 b). This extreme peak current value is of major interest for free electron laser development.
- Intense MeV photon beams from electrons in harmonically resonant betatron motion were measured by STRATH and IST teams at RAL, which is of major interest for applications.
- At GoLP/IST, the Lorentz boosted frame has been implemented and has allowed to simulate acceleration in the tens GeV range.

Victor Malka

[1] A. Buck et al., Nature Physics 7, 543-548 (2011), [2] O. Lundh et al., Nature Physics 7, 219-222 (2011), [3] S. Cipiccia et al., Nature Physics 7, 867-871 (2011), [4] S. F. Martins et al., Nature Physics 6, 311-316 (2010).

JRA ALADIN : Attosecond Laser sources and Applications; Design and Innovation

The Joint Research Activity ALADIN aimed at exploiting the recent progress of the new advanced generation of versatile and user friendly ultrafast sources, the proliferation of attosecond technology to a broad user community, and at exploring the full potential of these magic light sources in innovative science experiments. ALADIN can be considered a great success, basically all goals have been achieved, some developments even proceeded further. Here are some 'highlights' from the research that has been carried out within ALADIN.

CELIA has developed a setup for harmonic generation at very high repetition rate by using a diode pumped femtosecond system. This allows to generate high order harmonic at adjustable repetition rate ranging from 100 kHz to 1 MHz. Harmonics down to 33 nm have been generated in Ar at a repetition rate of 100 kHz.

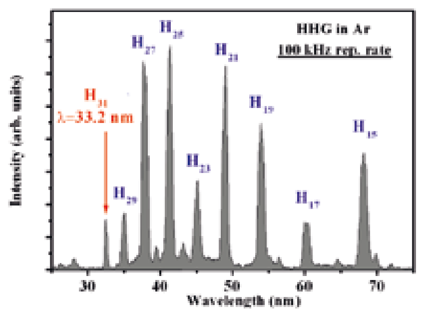


Fig. 1: Spectra of high order harmonics generated in Argon at high repetition rate (100 kHz) at CELIA.

A phase meter based on the stereographic measurement of photoelectrons has been improved such that the duration and the carrier-enevelope phase of few-cycle pulses can be measured for each and every pulse up to tens of kHz pulse repetition rate (FSU, MPQ). The method is based on the measurement of the asymmetry, i.e. the normalized difference in photoelectron yield for emission in opposite directions along the polarization axis of the laser pulse. The asymmetries for two ranges of photoelectron energy are used as Cartesian coordinates for a data point characterizing the laser pulse that has generated these photoelectrons. The pulse duration and the carrier-envelope phases can be deduced by analysing the respective radius and angle of the vector to a data point.

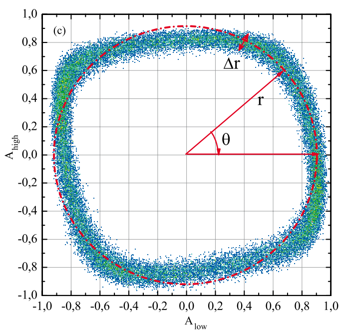


Fig. 2: The figure shows a few thousand data points corresponding to a sequence of laser pulses with a randomly varying carrier-envelope phase (FSU).

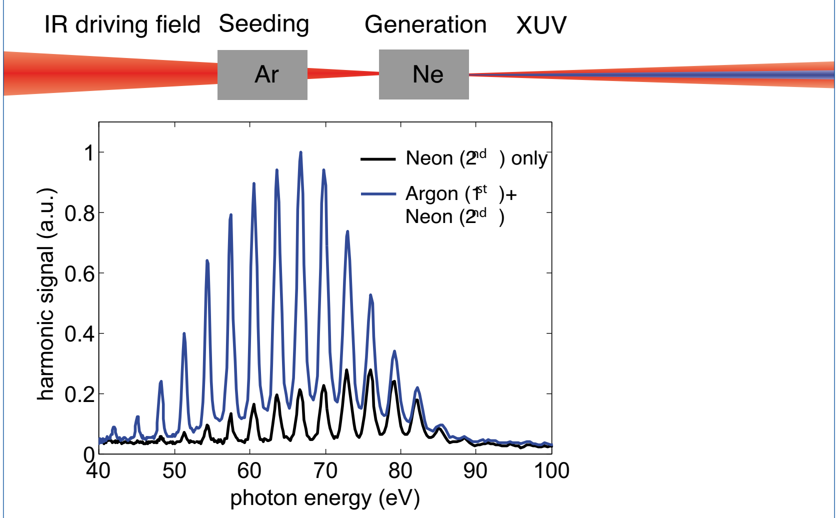


Fig. 3: Enhancement of the harmonic yield by using consecutive gas cells. At LLC, low-order harmonics are generated in the seeding cell to boost HHG in the generation cell.

At LLC the harmonic pulse energy was optimized to the µJ level: Enhanced harmonic generation was achieved by consecutive gas cells. The low-order harmonics are generated in the seeding cell to boost HHG in the generation cell.

In a two-colour setup, harmonics were generated by 800 nm + 1300 nm pulses at CLF: the short wavelength cut-off was extended from 40 eV to beyond 80 eV and an increase in yield by a factor of 100 was observed.

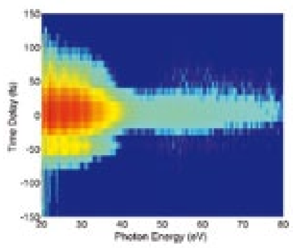


Fig. 4: Harmonic intensity as a function of delay between two laser pulses at 1290 nm and 780 nm with intensities 0.5 × 1014 Wcm-2. We observe an enhancement of more than 2 orders of magnitude and a cut-off extension from 40 eV to beyond 80 eV. © T. Siegel et al., Optics Express 18, 6853-6862 (2010).

Mutiphoton processes in the XUV have been studied at FORTH: surface plasma harmonics with 40µJ/pulse have been achieved and used for two-XUV-photon ionization of He. The 2nd order IVAC shows a train of 0.9 fs pulses. A temporal gating on the HHG process was achieved at POLIMI by using an intense 20-fs, 1.45-mm pulse (IR) in combination with an intense 13-fs, 0.8-mm pulse: a coherent continuous emission extending up to 160 eV using Ar and 200 eV using Ne has been efficiently generated.

At MPQ broadband XUV optics have been developed and produced. Well-defined dispersion was realized with multilayer mirrors. The streaking spectra show positive, zero and negative chirp, respectively, of the generated attosecond XUV pulses. Ramsey frequency combs have been generated from 51 nm to 85 nm, and applied for direct comb spectroscopy in He, Ne en Ar at LLAMS. Time resolved Angular Resolved Photoelectron Spectroscopy (tr-ARPES) of Gd has been performed at MBI using 35.6 eV.

SLIC has carried out tomographic imaging of molecular valence orbitals in N2 using the RABBIT technique. The overall structure, distances, and change of sign of the orbitals could be retrieved. LENS has developed a novel Random-Sampling Ramsey-like spectroscopic technique, employing high-order laser harmonics and a split-pulse Michelson setup, to perform absolute XUV frequency measurements in atomic Argon.

Reinhard Kienberger

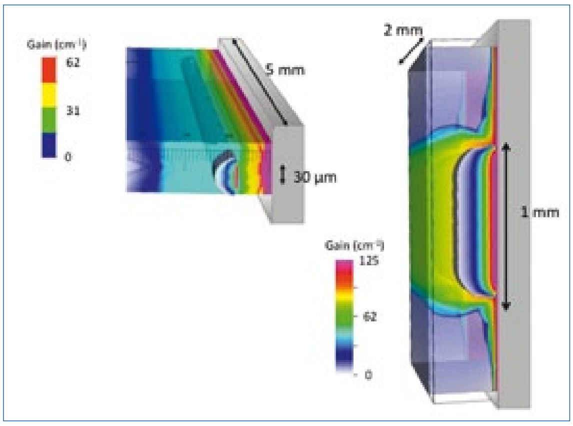
MBI newly developed table-top soft x-ray laser user station under commissioning.

JRA SFINX: Sources of Femtosecond Intense X-rays

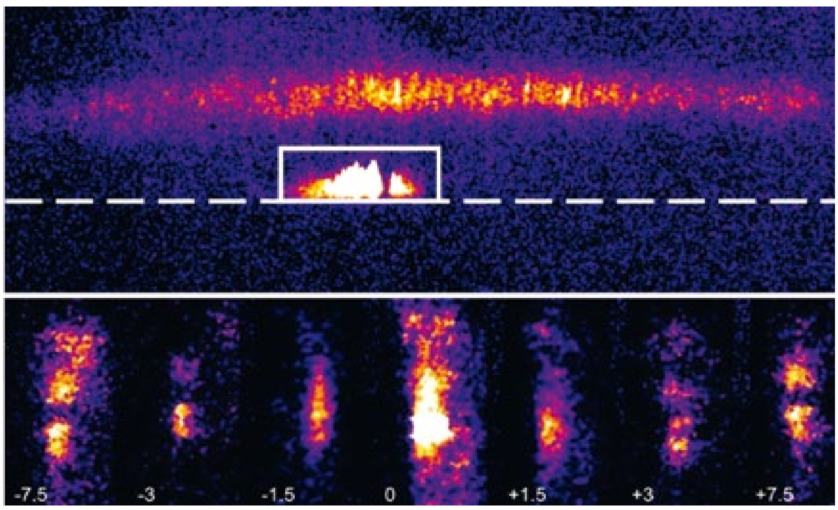
X-rays constitute one of the best tools for probing matter from the macroscopic to the atomic scale. Among all probing techniques, coherent x-ray imaging (CXI) is attracting much interest having demonstrated 2D and 3D images or "movies" of diversified samples with nanometre and often femtosecond resolution. CXI requires coherent, ultra-fast and energetic (from 10 µJ to several mJ) soft x-ray sources that are at the heart of SFINX' objectives.

Since the early 2000s, plasma-based soft x-ray lasers reached some level of maturity, but with still the limitation of being based on amplification of spontaneous emission that is intrinsically weakly coherent and non-polarized. With the recent technique of amplifying an external ultra-short (20 fs) soft x-ray seed, a polarized and fully coherent soft x-ray laser has been obtained. However, this technique did not succeed in keeping the pulse duration short - the shortest achieved being 1 ps- and output energy remained too low at about 1 µJ/pulse. SFINX aimed at unlocking these two problems.

IST, LASERIX, LOA, UPM and U. of York collaborated on improvement of the UPM's 2D hydrodynamic code, ARWEN, by implementing new ionisation or ray-trace routines, by testing ARWEN against real cases, by developing pure atomic physics as well as time-dependent Maxwell-Bloch codes to evaluate the ultimate amplified seed duration.



3D images of the plasma (transparent cube) and gain zone (inner rainbow cylinder) displayed in false colours for pump laser focal widths of 30 µm (left) and 1 mm (right).



Soft x-ray laser emission in two-plasma seed experiment with different synchronisations between the two plasmas. The intense (whiter) emission shows the amplification by the second plasma of the emission of the first one.

As a complement, the LIXAM team performed a unique comparison of the line widths of all soft x-ray lasers pumped by collisional excitation, using ps to ns driving lasers and even capillary discharge.

Hydrodynamic benchmarking experiments have been achieved at GSI, LASERIX, INFLPR and PALS facilities. These experiments offer new and valuable data for code developers. As an outcome, different architectures have been proposed and numerically tested, opening clear paths for LASERLAB facilities to implementation of soft x-ray lasers emitting pulses from about 20 µJ, 80 fs (0.2 GW) up to 6 mJ, 200 fs (3 GW), enabling to surpass today's most intense soft x-ray source (~ 0.5 GW).

Plasma hydrodynamics has also been optimized by GSI, LASERIX, MBI and INFLPR using so-called grazing incidence pumping (GRIP), leading, e.g., to the achievement of lasing with sub-Joule table-top pump lasers.

In parallel, LASERIX, MBI and MUT worked on innovative solutions to improve the soft x-ray laser technology with multi-jet gas targets, a new target holder compatible with 10 Hz repetition-rate, and optimized laser-target interaction allowing to shoot more than 2,000 times on the same target without refreshing it.

Reaching shorter wavelengths being a key issue for applications, LULI and LOA developed numerical codes for modelling inner-shell soft x-ray lasers with special focus on using the 'betatron' keV source as a pump. Developments are under way to model recombination scheme soft x-ray lasers.

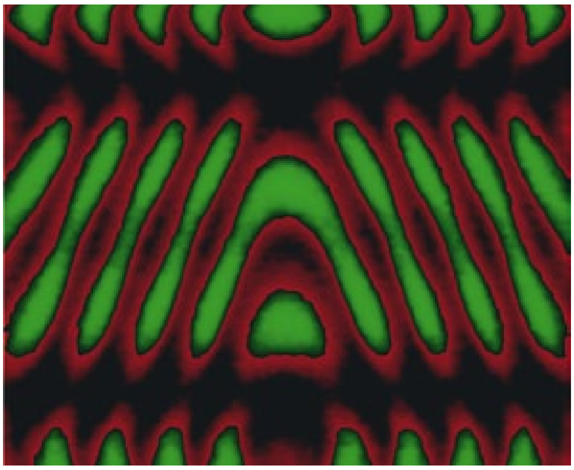
Philippe Zeitoun

JRA OPTBIO: Advanced Optical Techniques in Bio-imaging and Bio-processing

Over the last years, laser-based techniques developed in fundamental laser sciences, such as optical trapping, harmonic generation, and multiphoton excitation, have found their applications in biophysical research as non-invasive tools to manipulate molecules and to image cells and tissues, with unprecedented resolution and penetration depth.

The demand and interest from the biomedical community for application of these tools and development of new ones, to address open scientific issues and questions, is continuously growing. In particular, an increasing request is coming from molecular and cell biology for the visualization and manipulation of single molecules and cells and for the development of tools apt to image biological processes in living animals. A high demand is also rising from medicine, for the characterization of living tissues, and for disease diagnosis and therapy.

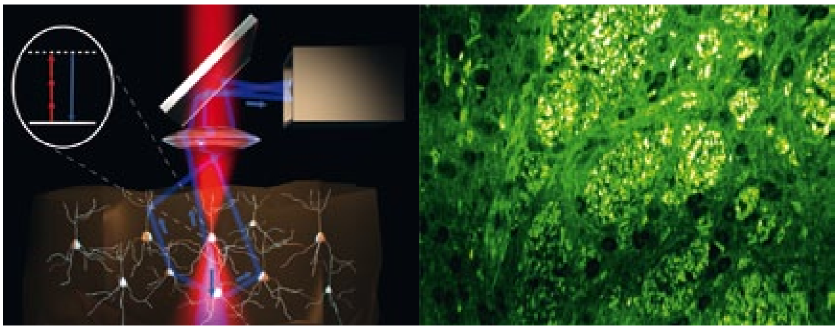
OPTBIO aimed at improving laser-based methods in biomedicine and providing access for the biomedical community to state-of-the-art instruments. OPTBIO pursued three main objectives, allowing the development of innovative workstations and methodologies, spreading from the investigation of single biomolecules and single cells to in-vivo microscopy on living animals to the development of diagnosis tools for human diseases.



SHG image of an intact muscle fiber. The image shows a line scan along the sarcomeric pattern (horizontal axis) versus time (vertical axis) during active contraction and subsequent relaxation. The SHG intensity is mapped using a false colour scale (from red to green).

The first objective addressed the need of efficient handling and imaging of tiny biological objects such as individual cells and molecules:

- LENS and LLAMS developed advanced platforms combining single molecule and single cell manipulation tools with single molecule fluorescence imaging, working both *in vitro* and in living cells.
- FORTH provided a laser-assisted workstation for subcellular surgery and processing and micro/nano structuring of biological, biocompatible and biodegradable materials using multiphoton polymerization.
- ICFO provided plasmonic micro and nano-structures with enhanced optical fields for in-plane optical manipulation and analysis.



Third harmonic generation microscopy through the mouse brain. Femtosecond laser pulses at 1200 nm excite the sample (red beam); blue emitted light is detected in backscattering.

The second objective was the improvement in capacities for advanced imaging beyond what is commercially available and the development of novel methodologies for the investigation of living cells and animals. Significant achievements have been obtained:

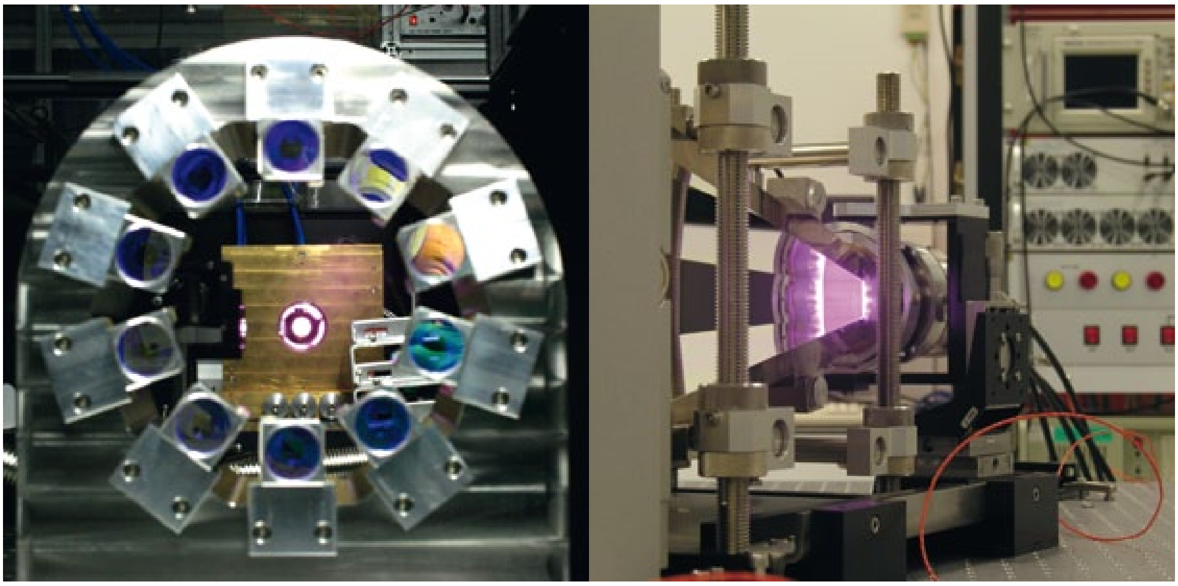
- for the development of multiphoton microscopy by LLAMS and ICFO,
- for the establishment of microscopy workstations with extend spatial resolution by LLAMS and ICFO,
- for the exploration of non-label methodologies by ILC.
- FORTH developed a workstation for combined two-photon and second and third harmonic generation microscopy.
- LENS and ICFO exploited second harmonic generation to image and measure structural dynamics of living muscle and neuronal cells.
- POLIMI designed and developed a first version of a pump-probe system to perform transient absorption in real-time.

The third objective was the development of optical techniques for *in vivo* imaging with the final aim of developing tools for medical diagnosis and optical therapy.

- POLIMI and LLC developed and potentiated their time-resolved diffuse spectroscopy systems leading to a great increase in dynamic range and reduction in acquisition time.
- FORTH has been adapting multispectral capabilities to their existing tomographic device.
- LENS coupled two photon imaging to laser-induced lesions to perform *in vivo* multiphoton nanosurgery in living mice brains.
- ICFO used different techniques to image at high resolution the process of nano-neurosurgery on the *C. elegans* nematode.
- VURLC developed a scanning multispectral imaging system.

Francesco Pavone

Multi-spectral fluorescence lifetime imaging microscopy setup with non-linear excitation developed at ILC.



MBI (left) and LULI (right) DPSSL laser heads.

JRA HAPPIE: High Average Peak Power lasers for Interaction Experiments

The HAPPIE Joint Research Activity built on high power/high rep rate European project investments. It targeted new technological developments centred on a high power mission, and was aligned to a vision of future high average, high peak power developments with:

1. DPSSL lasers designed and used to provide high average but low peak power.
2. High peak power being achieved by efficiently converting the low peak power output of the DPSSL laser chains into a high peak power through a non-linear interaction – Optical Parametric Chirped Pulse Amplification (OPCPA).
3. Single beam systems of (1) and (2) being finally coherently combined to further increase power.

The activities of objective 1 (DPSSL) were dedicated to face pumped thin disc technology and photonic rod fibres. Within this framework:

- MBI developed a multipass amplifier with 17 mm disc diameter delivering more than 550 mJ at a 100 Hz repetition rate.
- FSU concentrated its efforts on cryogenic studies with an efficient (>45%) CaF_2 laser source delivering more than 600 mJ.
- IST developed a Yb-based diode-pumped amplifier delivering 80 mJ at 0.5 Hz.
- LULI was able to achieve more than 10 joules at 2Hz with a water jets cooled Yb:YAG disk amplifier.
- CELIA developed a 47 fs photonic rod laser system delivering 8.6 W average power.

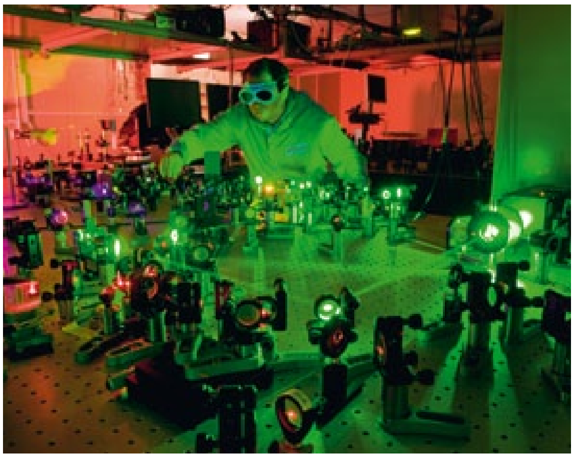
Activities for objective 2 (parametric conversion) were dedicated to non-linear combination, ultra-high contrast and OPCPA optically synchronized schemes:

- STFC developed a Joule level/35 fs laser system with a contrast after compression measured at 10^6 at 10ps and 10^{11} at 5ns.
- GSI reduced ASE with pulses partly stretched early in its amplifier chain.
- CEA measured thermal lensing in Ytterbium doped sesquioxides thin-disks lasers at low temperature and estimated the associated radiative quantum efficiency.
- CNR added an OPCPA preamplifier stage to its BLISS laser system while
- VULCR developed a high contrast NIR OPCPA system with an enhanced signal/ASE energy contrast.
- Finally, USZ developed a 150 fs 200 µJ source whereas
- PIVUT developed a mid-IR 3.9 µm OPCPA delivering 12-mJ 80 fs pulses at 20 Hz.

Activities for objective 3 (coherent aperture combination) were essentially dedicated to non-linear conversion schemes:

- STFC achieved two beam CW spatial coherence and temporal coherence in femtosecond pulses while
- CEA developed a numerical code to calculate phase-matching loci and associated angular tolerances in arbitrary geometries.
- VULRC developed a pump laser system for multi-beam energy combination in an OPA relying on 3 ns fiber amplifiers and
- INFLPR studied spectral coherent combination of ultra-short pulses and experimentally demonstrated non-linear power addition using spectral combination.

Jean-Christophe Chanteloup



STFC laser testbed for contrast studies.

Precision spectroscopy in ultracold helium

Test of Quantum ElectroDynamics and measurement of nuclear sizes

Atomic structure calculations for simple atoms such as hydrogen and helium can be tested with high precision using narrowband lasers and femtosecond frequency comb technology. Laser cooling and trapping of atoms allows long interaction times and observation and measurement of one of the weakest optical transitions in nature: the transition between the two long-lived metastable states of helium.

In a recent experiment carried out in the framework of the LASERLAB-EUROPE Transnational Access Programme, researchers from LaserLaB Amsterdam, the École Normale Supérieure (Paris) and the University of Auckland have been able to determine the relative size of the helium-3 nucleus (compared to the α-particle) with unprecendented accuracy – an order of magnitude more precise than Quantum ElectroDynamic calculations.

The observation of two series of emission lines in the helium spectrum at the end of the 19th century led physicists to think there were two kinds of helium: orthohelium and parahelium. In 1926 this observation was understood by Heisenberg on the basis of wave mechanics, electron spin, and the Pauli exclusion principle. We now know the orthohelium spectrum is due to electric dipole transitions between triplet states while parahelium lines originate from transitions between singlet states (see also Figure 1).

The first excited state states are from the 1s2s configuration, the ground state is $1s^2$. As the first odd-parity state lies above the 1s2s states, these states cannot decay by dipole transitions to the ground state. This makes them metastable. Atoms in this state can be cooled to microkelvin temperatures and trapped in magnetic and optical traps. This is the expertise of the LaserLaB VU group in Amsterdam.

Up to a million atoms can be loaded into a dipole trap, realized by focusing a few hundred milliwatts of light at 1557 nm in a crossed beam geometry (Figure 2). The atoms can be confined in this trap for about 10 seconds, long enough to excite with a second laser beam the transition between the two metastable states inside this trap. This transition is weaker by 14 orders of magnitude than the laser cooling transition at 1083 nm (the Einstein A-coefficient is 10^{-7} s^{-1}) and only allowed by magnetic dipole selection rules. Being so weak and narrow (8 Hz) an accurate measurement of the transition frequency allows a stringent test of Quantum ElectroDynamics (QED) theory for helium.

In the experiment, the researchers provided optimum conditions by cooling the helium atoms into the quantum degenerate regime, a Bose-Einstein condensate for ^{4}He and a degenerate Fermi gas for ^{3}He. This provides the smallest contribution from line broadening due to the motion of the atoms (Doppler effect). Also, the use of both isotopes of helium allows isolation of the tiny energy shifts due to the size of the nucleus.

While QED for the 2s-states of helium is accurate at the 1 MHz level of accuracy, energy shifts due to the finite nuclear size are of the same order of magnitude, rendering their measurement inaccurate when measuring absolute frequencies. However, measuring the isotope shift, QED effects cancel largely (they are essentially the same for both isotopes) while the nuclear shifts are very different for both isotopes as the nucleus of ^{3}He (the helion) has one neutron less than the α-particle and, surprisingly, a considerably larger radius.

The authors observed this transition for the first time and were able to measure the transition frequencies in both isotopes with a precision of 8 x 10^{-12} (~1 kHz), allowing a measurement of the helion charge radius of 1.961 (4) fm, where the accuracy is limited by our knowledge of the size of the α-particle.

Wim Vassen

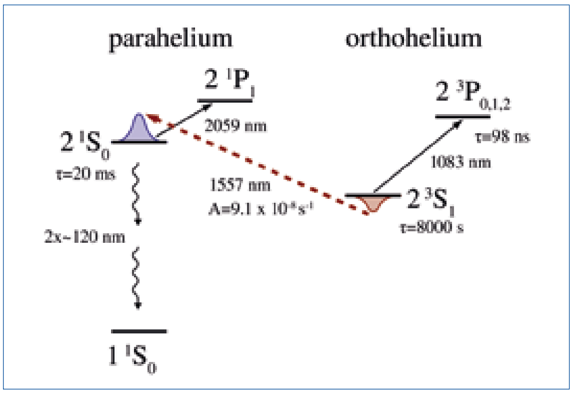


Figure 1. Energy levels, transition wavelengths and lifetimes of the lowest energy states of the helium atom. Helium atoms in the metastable triplet state (2^3S_1) are laser-cooled and trapped using the 1083-nm transition. The 1557-nm magnetic-dipole transition between both metastable states is measured in a dipole trap at the same wavelength. Triplet metastables are trapped at this wavelength while singlet metastables are antitrapped and leave the trap. © Science

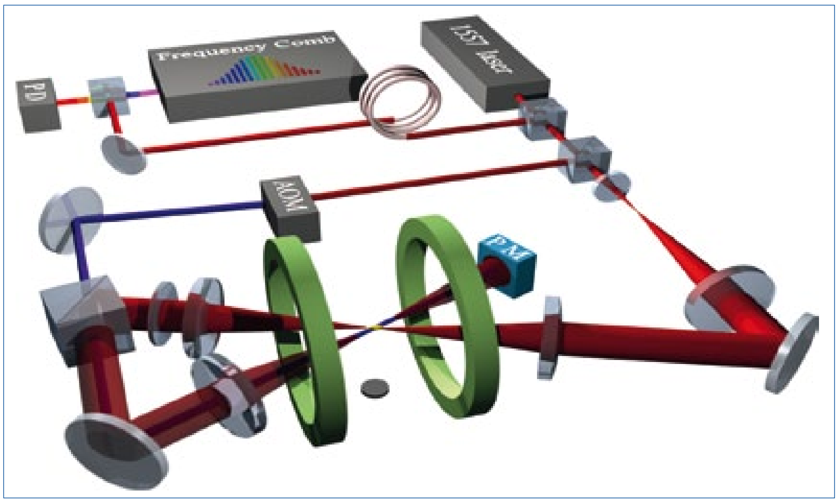


Figure 2. Experimental setup. A small fraction of the 1557-nm laser light is split off and coupled via a fiber link to be referenced to a frequency comb for absolute frequency measurement. The remaining light is divided into the trap beam and the spectroscopy beam. A crossed-beam dipole trap is realized by focusing the incident and returning beam (red) at the center of a magnetic trap (green coils), trapping the atoms at the intersection. The spectroscopy beam is frequency shifted by an acousto-optic modulator (AOM) and overlapped with the returning trap beam. A microchannel plate detector is mounted underneath the trap for temperature and atom number determination. © Science

van Rooij et al., Science 333, 196 (8 July 2011)

HiPER Participants' Forum and Fellow Meeting

Members of the HiPER project gathered in Bordeaux to participate in the 5th HiPER Participants' Forum and HiPER fellow meeting which took place in February 2012. The three-day event consisted of a tour of LMJ, the Forum meeting itself and the fellow meeting, where the scientists who have been directly recruited to undertake HiPER-specific research presented their recent results.

The participants' forum discussed the plans for national funding and the opportunities for access to Orion and PETAL.

The fellow meeting offered an opportunity to appreciate the significant contribution made by the young researchers of the HiPER community in a broad range of crucial areas including laser design, fusion technology and modelling of advanced ignition schemes.

The president of Region Aquitaine, Mr Alain Rousset, awarded prizes to Rafael Juarez for his oral presentation on "Studies of a Self Cooled Lead Lithium blanket and the implications in the design of HiPER reactor" and Lidia Borisenko for her poster on "Data processing for low-density high-Z nanoparticle layer characterization using x-ray tomography".

Anne-Marie Clarke and Jean-Christophe Chanteloup

ELI – Celebrating LASERLAB's new phase

The next few weeks and months will be filled with crucial milestones for the Extreme-Light-Infrastructure (ELI): the launch of the construction of ELI Beamlines near Prague, the final approval of ELI Nuclear Physics by the European Commission, the submission of the application for the funding of the ELI Attosecond facility, and finally the legal establishment of the ELI Delivery Consortium (see previous issues of Laserlab Forum for more details).

It is in this context that the highest ELI representatives of the Czech Republic, Hungary and Romania took part in the kick-off ceremony of the third phase of the LASERLAB-EUROPE Consortium on 15 March in Bratislava. In a joint address, they insisted on the decisive role that the consortium played in the past ten years in the advent of ELI by laying down the foundation for a sustainable culture of collaboration in transnational access and research, but also pushing the forefront of laser research in the direction of high-power high-energy lasers and particle acceleration. With its joint research activities, LASERLAB-EUROPE represents a crucial complement to the specific missions of ELI. Calling for a strong partnership between LASERLAB-EUROPE and ELI, the three representatives concluded by pointing out the urgent need for joint and ambitious action to cope with the future needs for qualified personnel of the European high-power laser facilities.

Florian Gliksohn

Eli plenipotentiaries at the LASERLAB-Europe kick off ceremony: Lóránt Lehrner (Hungary), Vlastimil Ruzicka (Czech Republic) and Nicolae Zamfir (Romania)

Forthcoming events

21-22 May 2012
Foresight Workshop
Time-resolved X-Ray Imaging
Aghia Pelagia, Crete, Greece

24-25 May 2012
Workshop "Infrastructures for Lasers"
Bordeaux, France

11-13 June 2012
Networking Activity on High Energy Lasers (NAHEL) – Annual Meeting
Cosener's House, Abingdon, UK

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 USP. The USP will then take a final decision. In case the proposal is accepted the host institution will instruct the applicant about further procedures.

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