Issue 20 | November 2015

Laserlab Europe

# Laserlab Forum

Newsletter of LASERLAB-EUROPE:
the integrated initiative of European laser
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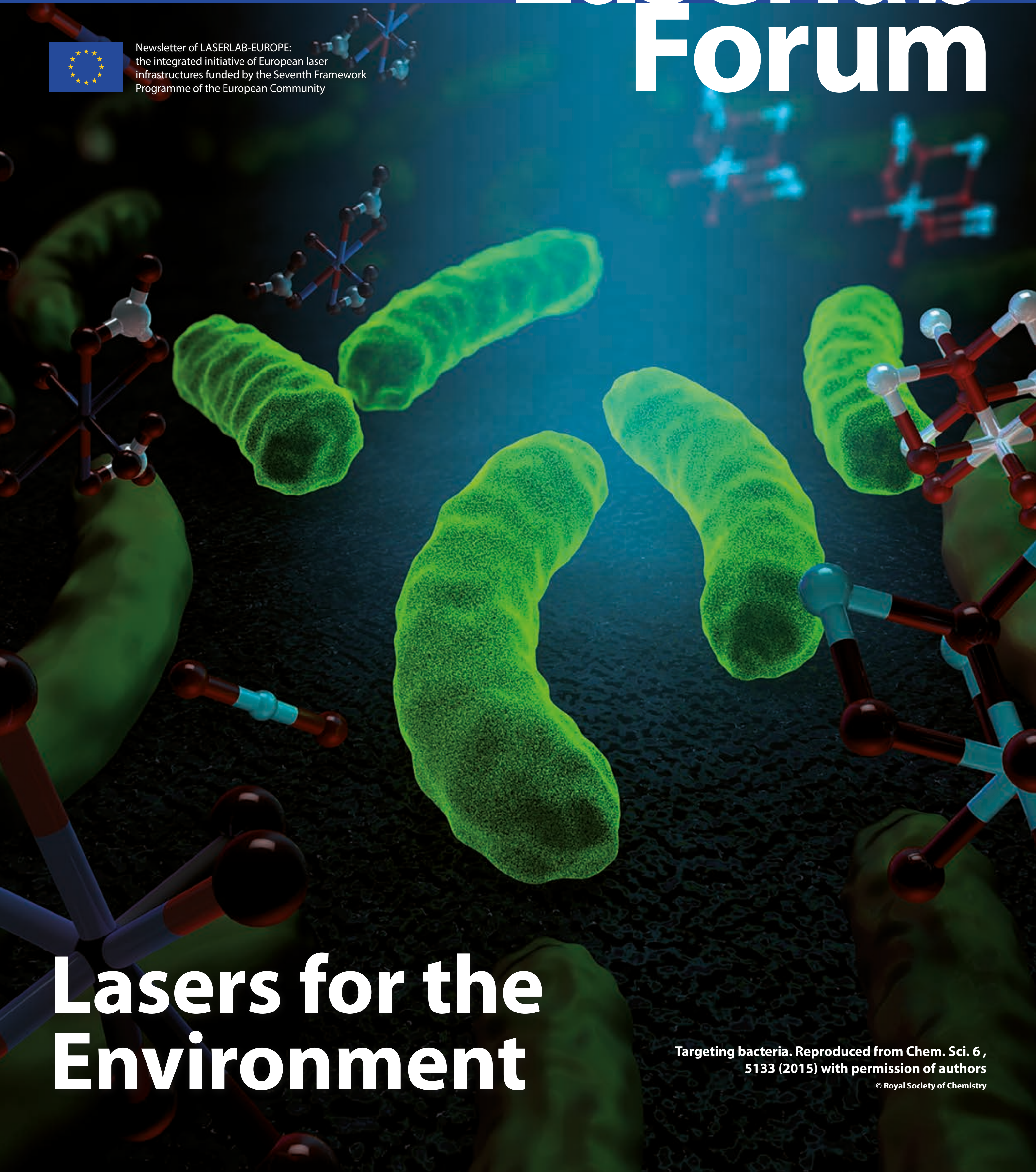

## Lasers for the Environment

Targeting bacteria. Reproduced from Chem. Sci. 6 , 5133 (2015) with permission of authors

## In this Issue





# Editorial

*Tom Jeltes*

As laser scientists know, not every focus is as tight as the other. In a recent issue of this newsletter, we had a focus section about Lasers for Solar Energy. Quite a narrow, specialised focus compared to the current feature: Lasers for the Environment. Under this header, we find a broad range of topics, ranging from laser systems used to find microbes in the sky (developed in the context of countering biological warfare, and used to monitor the environment during the Euro 2012 Football Championships in Poland), to a system to assess the handedness of pesticide molecules, and one to find low concentrations of harmful toxins. But lasers can also be used to study the behaviour of uranium-eating microbes, which might make themselves useful cleaning polluted soil in the future.

A yet very different – but certainly not less important – application of lasers is in the study of combustion processes, which have a huge impact on the quality of our environment. Combustion expert Marcus Aldén from Lund Laser Centre recently received his second ERC Advanced Grant, and a short description of his project is included in the focus section. Two other members of the Laserlab-Europe community, Niek van Hulst (ICFO) and Wim Ubachs (LaserLaB Amsterdam) also received this prestigious 2.5 million euro grant this year, for research on photosynthesis and the quest for new physics, respectively. In this issue, more can be found about their projects as well.

Speaking of a broad focus: this issue's Access Highlight explains how detailed measurements on chemical compounds in the lab could heighten our understanding of what goes on in outer space…

**Tom Jeltes**

# News

## Symposium in memoriam of Savas Georgiou

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**A symposium dedicated to the memory of Savas Georgiou, former Research Director of IESL-FORTH, was held on 28 September 2015. At this special event Georgiou's scientific contributions were highlighted and memories from his everyday interaction with students and colleagues were presented. The symposium was concluded with the inauguration of a new laboratory on advanced materials laser nano-processing (www.iesl.forth.gr/ULMNP) within the premises of IESL-FORTH, named after Savas Georgiou.**

Savas Georgiou (1961-2012) was born in Athens. He received his B.Sc. in chemistry and mathematics from Knox College, Illinois, and his Ph.D. in physical chemistry (on the study of photodissociation dynamics of organometallic compounds) from the University of Utah. He subsequently performed postdoctoral work on Raman spectroscopy of biomolecules at Princeton University. In 1992, Georgiou joined IESL-FORTH, where he was promoted to Research Director in 2007. His scientific interests focused on studies of laser ablation, laser photochemistry and biophysics, and laser material processing schemes. His scientific research activity was unexpectedly interrupted in 2009 due to a serious health problem.

## PETAL laser breaks petawatt power barrier

**On 29 May 2015, PETAL (PETawatt Aquitaine Laser) near Bordeaux delivered a power of 1.2 petawatt (1 PW = $10^{15}$ watt), rendering it the first facility capable of overcoming the petawatt power barrier at the highest energy level within one beamline. PETAL supplied 846 joules of laser energy at a wavelength of 1053 nanometre in a 0.7 picosecond pulse. The facility was inaugurated at the CEA-CESTA centre on 18 September**

© CEA-MS-2015

*PETAL compression chamber.*

**2015 by the President of the Aquitaine Region, Mr. Alain Rousset.**

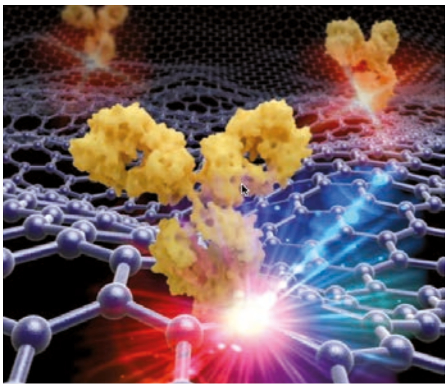
The PETAL project is being operated by CEA (French Alternative Energies and Atomic Energy Commission) under the financial auspices of the Aquitaine Region (as project owner), of the French Government and of the European Union. Incorporated in the CEA Megajoule Laser Facility (LMJ) near Bordeaux, France, this instrument confirms CEA at a leading position worldwide for building and exploiting powerful lasers. The installation of PETAL is part of the policy of the French Ministry of Defense to open and share the LMJ facility to the civil research community.

## Mid-infrared graphene molecule sensor

**Researchers from Laserlab-Europe partner ICFO, in a collaboration with EPFL's Bionanophotonic Systems Laboratory (Lausanne), have created a new device in which they have harnessed graphene's unique optical and electronic properties to develop a reconfigurable highly sensitive molecule sensor. The results are described in an article that appeared in Science journal in July 2015.**

Because of the long wavelength used, infrared absorption spectroscopy has important limitations when applied to small molecules. Given the correct geometry, however, graphene is capable of focussing light on a precise spot on its surface and "hearing" the vibration of a molecule that is attached to it. In this study, researchers patterned nanostructures on the graphene surface which concentrate light into tiny spots, comparable with the dimensions of the target molecules. It is then possible to detect compounds of nanometre size in proximity to the surface.

In addition to identifying the presence of nanometric molecules, this process can also reveal the nature of the bonds connecting the atoms that make up the molecule. The researchers "tuned" the graphene to different frequencies by applying voltage, which is not possible with current sensors.



© Miguel Spuch, Daniel Rodrigo (EPFL)

*Illustration of the mid-infrared graphene molecule sensor.*

## What is Laserlab-Europe?

Laserlab-Europe, the Integrated Initiative of European Laser Research Infrastructures, understands itself as the central place in Europe where new developments in laser research take place in a flexible and co-ordinated fashion beyond the potential of a national scale. The Consortium currently brings together 30 leading organisations in laser-based inter-disciplinary research from 16 countries. Its main objectives are to maintain a sustainable inter-disciplinary network of European national laboratories; to strengthen the European leading role in laser research through Joint Research Activities; and to offer access to state-of-the-art laser research facilities to researchers from all fields of science and from any European laboratory in order to perform world-class research.

## France inaugurates APOLLON Laser

**The new laser facility APOLLON has been inaugurated on 29 October 2015 in the presence of Mr. Thierry Mandon, French State Secretary for Higher Education and Research and representatives of funding agencies and academic institutions. APOLLON is the result of a large common effort of 12 laboratories from the Plateau de Saclay with complementary expertise in lasers, plasmas, accelerators, high-energy physics and radiation sources.**

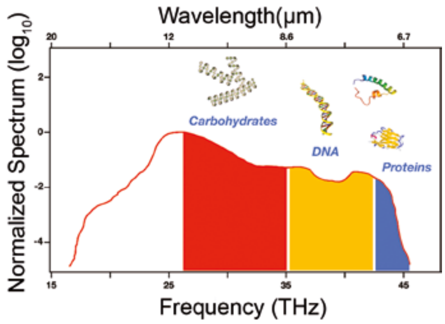
Starting at a level of 1 petawatt (PW) in 2016 and 5 PW in 2017, the main laser beam of APOLLON will be able to reach 10 PW in the near future, in pulses of 150 joules in 15 femtoseconds. Complemented by three additional beams, including a 1 PW, 15 joule, 15 femtosecond beam, and two dedicated experimental areas, APOLLON will allow scientists from France, Europe and other countries to develop original research programs in unexplored extreme conditions.

Thanks to the high energy per pulse and to the extreme power, experimentalists can either profit from high intensities over long distances and large focal spots, or extreme intensities, up to $10^{22}$ W/cm$^2$ in the nominal configuration. After internal tests and commissioning in 2016 and 2017, APOLLON will be progressively open to the community from 2018.

## Laser pulses for molecular fingerprints of cancer cells

**Researchers from the Attoscience and Ultrafast Optics Group led by ICREA Prof. Jens Biegert at ICFO, in collaboration with the Max Planck Institute for Quantum Optics (MPQ) and the Ludwig-Maximilians-Universität (LMU) in Munich, have developed a worldwide unique broadband and coherent infrared light source. The record peak brilliance of the light source makes it an ultra-sensitive detector for the infrared molecular fingerprint region, ideal to detect minute changes in the spectral features from cells or tissue which are tell-tale signs of DNA mutation or the presence of cellular malfunctions such as cancer.**

The absence of light sources that cover enough of the infrared spectrum with sufficient brilliance to detect minute concentrations of cancer-related molecules has been the main challenge in cancer detection. Now, ICFO researchers have collaborated with colleagues from MPQ/LMU to develop a light source which addresses this need. Their light source exerts extreme control over mid-wave infrared laser light with unrivalled peak brilliance and single-shot spectral coverage between 6.8 and 16.4 micron wavelength. Jens Biegert and his colleagues at ICFO are currently investigating molecular sensitivity for the identification of cancer biomarkers on the single cell level using all optical techniques in the mid-wave infrared wavelength range.




*Emission spectrum of the laser and molecular fingerprint regions. © ICFO*

## Stefan Eisebitt appointed as Director at MBI

**Stefan Eisebitt has been appointed as one of three Directors at the Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy and as Professor at the Technical University Berlin, Germany.**

As of November 2015, he is successor of Wolfgang Sandner at MBI. Eisebitt's main areas of research are ultrafast electron and spin dynamics, magnetic nanostructures and imaging.

# ERC Advanced Grants

The Advanced Grants awarded by the European Research Council (ERC) allow exceptional established research leaders of any nationality and any age to pursue ground-breaking, high-risk projects that open new directions in their respective research fields or other domains. This year, three scientists from Laserlab-Europe partners received this prestigious grant: on this page, more can be read about the Advanced Grant projects of Niek van Hulst (ICFO, Barcelona) and Wim Ubachs (LaserLaB Amsterdam). More about the third grantee, Marcus Aldén from Lund Laser Centre, can be found in the focus about Lasers for the Environment on the next page.

## Niek van Hulst (ICFO): LightNet


*Niek van Hulst*

**Signs of quantum coherence have been found in biological systems that are active in photosynthesis, suggesting that plants, algae, and bacteria may use quantum phenomena to efficiently store solar energy in the form of sugars. Recently, the group of Niek van Hulst from Laserlab-Europe partner ICFO were the first to detect coherent oscillations at physiological conditions in a single photosynthetic complex – the network of biomolecules involved in the capture, conversion and storage of solar energy. Van Hulst has now received his second ERC Advanced Grant for a project, LightNet, to find out if and how nature employs these unexpected large-scale quantum effects for photosynthesis.**

Advances in ultrasensitive and ultrafast experimental spectroscopy have revealed evidence of so-called 'quantum coherence' in the energy transfer of light-harvesting complexes of bacteria, algae and plants. This quantum coherence might be the reason for the remarkably high efficiency (95%) of photosynthetic light harvesting, as it would allow the complex to find the most efficient pathway for the energy transfer, but until recently it was thought that such quantum phenomena could never occur on the scale of biological systems.

So far, quantum coherence has only been seen in light-harvesting complexes in solution; there is as yet no observation of the effect *in vivo*. The aim of van Hulst's project is to find out if the observed quantum phenomena do indeed serve any biological role, and how these coherences can be sustained (a question especially relevant for the application of quantum coherence to solar energy technology).

In order to observe what is going on inside and between the light-harvesting complexes, van Hulst and his team will use several novel detection methods, such as optical antennas and graphene-based electrical read-out devices developed at ICFO, and stimulated emission techniques. Using excitation and detection by nanoholes, nanoslits and scanning antenna probes, van Hulst will try to map the energy transfer between the complexes on the nanoscale and combine this data with coherent femtosecond excitation schemes to track the coherences throughout the network.

## Wim Ubachs (LaserLaB Amsterdam): NEWPHYS-MOLECULES

*Wim Ubachs*

**The Standard Model of physics is incomplete. Gravity is not understood at the quantum level, dark matter and dark energy are not explained, and (string) theories searching to cover these shortcomings are only consistent in higher-dimensional spaces, while only four of those dimensions are observed. Moreover, there is the unexplained mystery of finely tuned strengths of the fundamental forces, providing us with a Universe of complexity. With his ERC Advanced Grant project NEWPHYS-MOLECULES, Wim Ubachs from LaserLaB Amsterdam will perform precision metrology measurements on the $H_2$ molecule in a search for new physics that might provide answers to these fundamental questions.**

The paradigm underlying Ubachs' proposal is that effects of new physics – either related to unknown particles or to symmetry-breaking phenomena – will manifest themselves as tiny shifts in the quantum level structures of atoms and molecules, or in minute drifts over time or dependencies on environmental conditions. Phenomena that can be explored also at the atomic scale in the low energy domain.

Ubachs' plan is to confront molecular metrology results of the fundamental ground tone vibration in $H_2$ with QED-theory calculations to search for the existence of new forces at the Angström length scale ($10^{-10}$ m). If extra dimensions beyond the known 3+1 would be compactified at the same length scale of 1 Å, this would lead to strongly enhanced gravitational effects, measurable in a molecule.

Ubachs' current research on experimental probes for varying constants on a cosmological time scale will be redirected into the investigation of chameleon scenarios: the idea that dark energy is related to a fifth force, of which the range would strongly depend on the properties of the environment, such as energy density or gravitational fields. This would make this fifth force almost impossible to see on Earth, but possibly detectable in interstellar space. Ubachs is planning to study $H_2$ molecules in white dwarf stars by UV astronomy, and methanol molecules in our own galaxy by radio astronomy, searching for a possible dependence of fundamental constants on strong gravity or on density.

# Lasers for the Environment

A clean and healthy environment is of utmost importance for all living beings. 'Nature is our life support system, so we have to look after it', as the European Union puts it. Laser science can be used in many, very different ways to contribute to a better environment. By measuring toxins or biological agents, for example, or by studying microbes that might be used for soil cleaning. But lasers can also be instrumental in developing cleaner combustion processes. In this focus section, a number of projects from partners of Laserlab-Europe are presented that are beneficial, in one way or the other, to our precious environment.

## ERC Advanced Grant for laser diagnostics of combustion processes (LLC)

*Marcus Aldén*

**Emissions from combustion processes are the main source of today's air pollution and a major source of global warming. Cleaner and more efficient combustion devices thus have a huge positive impact on the environment. The Division of Combustion Physics of Lund Laser Centre (LLC, Lund, Sweden) has been studying the details of combustion processes for several decades now, and has built up one of the world's best equipped laser-diagnostic labs with numerous state-of-the-art lasers and detectors. This year, Marcus Aldén, head of the Combustion Physics Division, has been awarded his second ERC Advanced Grant for his proposal: 'Towards a deepened understanding of combustion processes using advanced laser diagnostics'.**

In (partially) transparent combustion devices, laser light can be used to study the combustion dynamics and probe the presence of different chemical species in the flame with a high temporal and spatial resolution, without influencing the combustion process itself. Marcus Aldén has been using lasers for this purpose for thirty-five years. With his ERC Advanced Grant, Aldén will develop new diagnostic techniques and perform several phenomenological combustion studies.

One of the new techniques is spatially structured laser illumination of gases and fluids during combustion, which will allow instantaneous three-dimensional imaging of the combustion process by probing different sections of the flame using several differently structured laser beams. Another line of research planned by Aldén uses ultra-short laser pulses (of pico- and femtosecond duration), which cause the investigated gas mixture to act as a lens for the laser light, thereby creating a very thin channel of light, called a laser-filament. In this filament, a backward lasing effect might be induced, which would open up multiple diagnostic possibilities.

The combustion phenomena that Aldén plans to investigate include detailed flame studies at –industrially relevant – high pressure and turbulent circumstances, as well as the gasification and combustion of solid biomass – an emerging major technology yielding a $CO_2$-neutral fuel for power, heat, and transport. Finally, Aldén and his team will use laser diagnostics to study electrically assisted combustion, where microwaves and discharge plasmas are employed to accelerate and control combustion processes.

*www.forbrf.lth.se*

## Detecting hazardous particles in the sky with LIDAR (MUT-IOE)

**LIDAR (Light Detection and Ranging) gains more and more attention in Poland due to the successful experiments carried out by the Institute of Optoelectronics (IOE) from the Military University of Technology, Warsaw, Poland. The researchers from IOE built a multifunctional fluorescence-depolarisation LIDAR system for stand-off detection of biological clouds at distances up to several kilometres. The efficiency of the LIDAR system was proved in a number of field tests, both in Poland and abroad.**

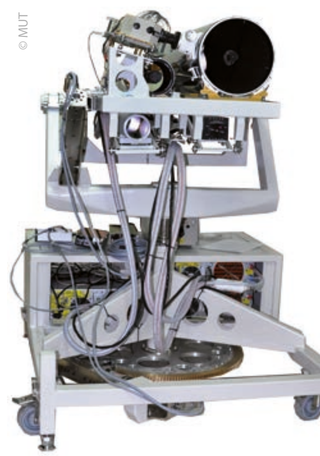
LIDAR is not only able to distinguish biological particles from non-biological background, but also to classify the type of detected species. This is accomplished by the application of a hyperspectral detection approach combined with scattering/depolarization data fusion. Like fingerprints, the detected signals are compared with a database to find the closest match.

Bio-LIDAR was included in the security activities conducted by the Polish government during the European Championships in Football – EURO 2012. The system was installed on one of the top floors of the Culture Palace in the city centre of Warsaw and the air content above the National Stadium (located about three kilometres away) was continuously monitored during the games. Also, a miniaturised version of the "big" LIDAR system was created, capable of measuring at distances up to several hundred metres. It was also used during EURO 2012 to monitor the fan zone located directly beneath the Culture Palace.

The developed LIDAR system proved its high operational value during field tests at Dugway Proving Ground (DPG) in the USA, where full calibration, database optimisation and sensitivity verification were performed. The facilities of DPG allowed the measurements of biological aerosols dispersed at known concentrations to be carried out in specialised chambers. The LIDAR instrument, located 1200 m away, was able to detect 0.01 g of biological simulant added and mixed with air inside a building-sized tunnel. This corresponds to an astonishingly low volume concentration level of several hundred ppl (particles per litre). Additionally, open air blind tests were

*The LIDAR instrument.*





performed, where the LIDAR system was scanning a certain angular range of terrain ahead and chased clouds to distances up to five kilometres. Simulants were released at unknown positions and moments of time, so the system operated in real-life conditions as an early warning component. It performed extremely well both in terms of detection and classification. Clearly, the LIDAR technology in Poland approaches readiness for commercial implementation.

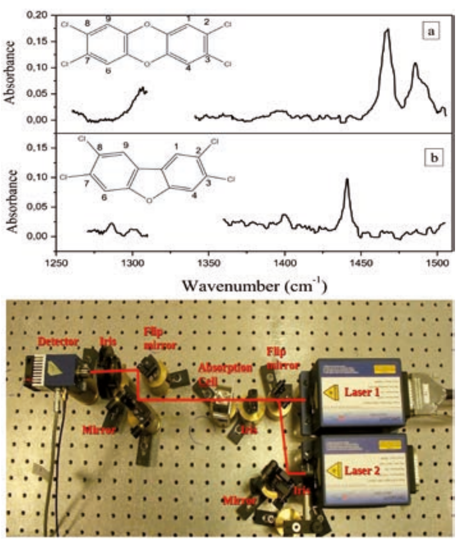
**Jacek Wojtanowski**
*www.ioe.wat.edu.pl*

## IR spectroscopy of dioxins and furans with quantum cascade lasers (LENS)

**Polychlorinated Dibenzo-p-Dioxins (PCDDs) and Polychlorinated Dibenzo-Furans (PCDFs) are ubiquitous and persistent organic pollutants characterised by extreme toxicity and widespread occurrence in the environment. In a collaboration with the Italian National Institute of Optics (CNR-INO), the European Laboratory for Non-Linear Spectroscopy (LENS, Florence, Italy) has been able to achieve a quantitative analysis of the concentration of several dioxins and furans, among which the most toxic ones, by only using infrared absorption laser spectroscopy.**

Dioxins and furans are mainly produced by incineration of domestic, industrial and hospital waste, as well as by natural combustion processes. The possibility of real-time monitoring of these pollutants is therefore crucial to insure immediate counteractions in case of malfunctioning of incineration plants.

Up to eight chlorine atoms can be placed on the two benzene rings, giving rise to 75 types of PCDD and 135 PCDFs. Among these 210 polychlorinated molecules, the 2,3,7,8-tetrachlorinated (TCDD) species have the highest toxicity. Two broadly tunable quantum cascade lasers (QCLs), emitting in the mid-infrared (MIR), have been used to measure the absorption spectra of dioxins and furans, dissolved in carbon tetrachloride (CCl4), in direct absorption mode. In the two considered MIR regions, 1260–1310 $cm^{-1}$ (QCL1) and 1340–1510 $cm^{-1}$ (QCL2), the absorption bands are located such that they are useful for identification of the different types of toxic chemicals.




*Picture of the experimental setup (upper panel) and absorption spectra of 2,3,7,8-TCDD (a) and 2,3,7,8-TCDF (b) (molecular structures shown in the inset) dissolved in CCl4 at concentration of 0.1 mg /ml (lower panel). Reproduced from Siciliani de Cumis et al., Laser Phys. 23, 025603 (2013)*

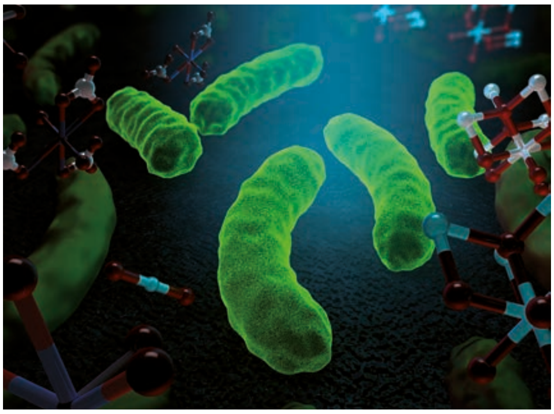
The emission limit of dioxins for incinerator plants in Europe is set by law to 0.1 ng/$Nm^3$. The laser setup shown in the figure allowed the measurement, among others, of the most toxic dioxin (2,3,7,8-TCDD). At present, the instabilities of the laser system do not allow to reach such limit but we proved that once the laser is stabilized, the condition to achieve the requested sensitivity is feasible. Moreover, we have demonstrated that using a hollow fibre instead of a normal liquid transmission cell, it is possible to further enhance the measurement sensitivity.

**Barbara Patrizi and Mario Siciliani de Cumis**
*www.ino.it, www.lens.unifi.it*

## Microbes for natural cleaning (CLF)

**Micro-organisms might be able to help convert toxic waste to harmless chemicals, or could be used to prevent radioactive materials from spreading in soils. Several research teams are using the equipment available at the UK's Central Laser Facility to find out how microbes could help clean the environment.**

Using the Raman optical trapping capability, single bacteria can be captured and the Raman spectrum obtained to provide a finger print of the chemical make-up. The technique has been used by a team led by Professor Wei Huang (University of Oxford) to identify which species of bacteria digest specific compounds by analysing peak shifts from the incorporation of chemical isotopes. The technique offers the potential to determine strains of bacteria that can break down and bio-remediate specific pollutants. Simple microfluidic devices are used to enable sorting of bacteria species using laser-based manipulation techniques.



*Targeting bacteria: Representation of fluorescence lifetime microscopy on Geobacter sulfureduccens microbes containing uranyl acetate. (Reproduced from Chem. Sci. 6, 5133 (2015) with permission of authors, © Royal Society of Chemistry)*

Another team of scientists from Manchester University, headed by Dr Louise Natrajan, is using facilities at the Central Laser Facility to investigate how microbes can help prevent radioactive waste materials from spreading in soils. Certain micro-organisms, such as bacteria, fungi and algae, can bind and accumulate radioactive material through biosorption. There are some strains of bacteria associated with soils that are capable of facilitating a chemical reaction whereby the radioactive material no longer dissolves in water. Such behaviour can markedly alter transport of this waste in the environment. At the Central Laser Facility laser-based imaging techniques are used to monitor the properties of uranium compounds in bacteria to provide fundamentally important information on both the micro-environment and chemical reaction processes. Lasers are used to target individual bacteria that are imaged using techniques of fluorescence lifetime and phosphorescence lifetime imaging. The results from the team's most recent studies suggest that localisation of uranyl species (oxidised uranium) on both the cell membrane surface and outside of the cell play an important role during early stages of the bioreduction.

**Andy Ward**
*www.clf.stfc.ac.uk/CLF/*

## Discriminating between chiral pesticides (LaserLaB Amsterdam)

**Around 30% of pesticides consist of so-called chiral molecules: they exist as two or more species (called *enantiomers*) that are non-superimposible mirror images of each other. Often, one of the enantiomers is much more toxic or less biodegradable than the other. In a recent transnational access project at LaserLaB Amsterdam in the Netherlands, published in Nature Communications, it was shown that a novel laser technique, called mass-selective photoelectron circular dichroism (MS-PECD), is capable of discriminating between different enantiomers.**

Chirality matters a lot in Nature. Many enzymes only act on molecules with a specific handedness, while they ignore molecules that have a different chirality but are otherwise identical. This causes different enantiomers to have a significantly different impact on the environment. Because of their production process, pesticides used in agriculture often consist of equal mixtures of each enantiomer, of which only one targets the pests for which it was chosen, while the other chiral species might have an adverse effect on non-targeted organisms.

Because pairs of enantiomers are so much alike, distinguishing between them is a challenging task. As has now been shown at LaserLaB Amsterdam, mass-selective photoelectron circular dichroism (MS-PECD) could provide a table-top solution for enantiomer-specific identification of chiral molecules in multi-component mixtures. The technique might therefore be used to study effects of chiral molecules and volatile organic compounds (VOCs) in different ecosystems.

MS-PECD is a special type of mass spectrometry, in which circularly polarised femtosecond laser pulses are used to ionise chiral molecules with multiple photons. By carefully combining information about the time it takes for the ions to travel to one detector and about the direction in which the electrons are ejected (registered by a second detector in coincidence), the molecular species as well as the ratio between both chiral varieties can be deduced.

The access experiment was a collaboration between Ivan Powis from the University of Nottingham, who had already demonstrated the principle using synchrotron radiation, and a team from Amsterdam led by Maurice Janssen. The latter recently left his position as a professor at LaserLab Amsterdam to focus on the commercialisation of the MS-PECD, which would also have applications in pharmacy and the food sector.

*www.laserlab.vu.nl, www.massspecpecd.com*

## Raman laser spectroscopy for environmental monitoring (IPHT)

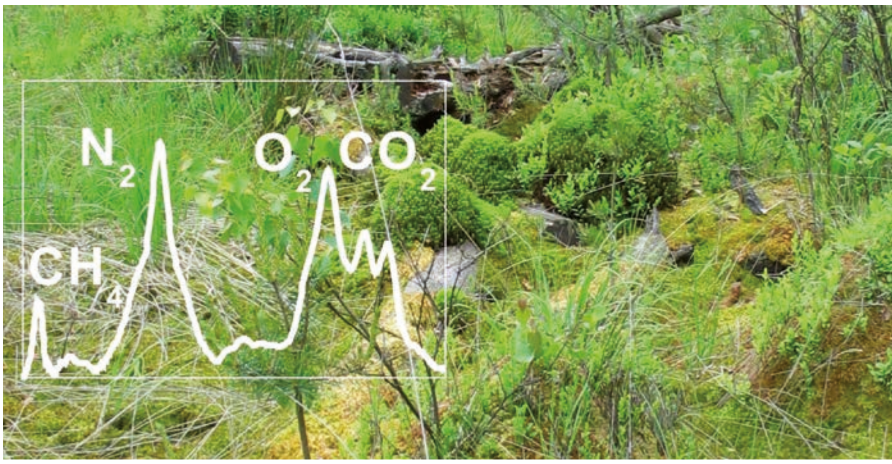
**At IPHT Jena, Germany, Torsten Frosch's 'spectroscopic sensors' group develops laser spectroscopic setups for highly sensitive Raman multi-gas sensing. With the help of novel optical hollow fibres and optical cavities, strongly enhanced sensitivities are achieved for environmental monitoring, as well as for analysis of disease biomarkers in breath. The applications of this novel laser Raman spectroscopic developments are of importance for studying, for example, the impact of climate change.**

As the Earth's temperature rises, part of the permafrost in Siberia and other regions will melt, thereby releasing huge amounts of methane and other greenhouse gases. Raman gas spectroscopy could be used to measure in real time the emission of $O_2$, $CO_2$, $CH_4$ and $N_2$ from thawing permafrost, as was shown in a study where the concentrations and fluxes of these biogenic gases were measured in the head space of water-saturated, raised peat bog. In order to determine important ecosystem parameters such as the maximum photosynthesis rate and plant respiration, the peat bog was exposed to various light regimes.

In a different study, the respiratory quotient (the amount of $CO_2$ released per $O_2$ consumed during respiration) of pine and spruce trees was monitored by cavity-enhanced Raman multi-gas spectrometry. Real-time measurements of the respiratory quotient give excellent insight in how plants cope with stress factors such as drought and shading, but because the gas exchange fluxes are very small, this analysis had so far been very challenging.

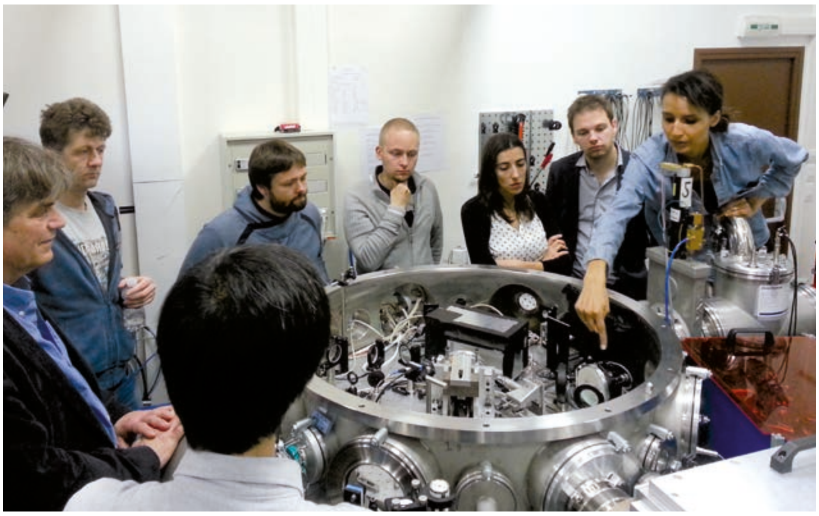
Another important application is in monitoring resource flows in plants using the carbon dioxide isotope $^{13}CO_2$, which is taken up by plants from the air during photosynthesis. As was shown in an experiment on poplar trees, since the carbon isotope $^{13}C$ can be distinguished by cavity-enhanced Raman spectroscopy, the journey of these atoms through the entire plant can be tracked. This new technique thus adds a valuable new tool for the study of metabolism, from the scale of organisms to ecosystems.

*www.ipht-jena.de/en/research-units/research-departments/spectroscopy-imaging/spectroscopic-sensors.html*




*Emission profile of moorland. From Analytical Chemistry 85, 1295 (2013).*

# Laserlab Workshops





## Laser Plasma Targetry Workshop

**The international Laser Plasma Targetry workshop second edition (TARG2), co-organised by the French Laserlab-Europe partner LOA, its spinoff company SourceLAB, Ludwig-Maximilians-Universität Munich and Université Pierre et Marie Curie (Paris), was held in Paris on 20-22 April 2015.**

The workshop, which gave priority to PhD students and young scientists, attracted about seventy researchers and students keen on debating the pivotal topic of targetry and diagnostics for enhanced control of the interaction between intense lasers and plasmas.

The participants discussed which developments should take place in order to make laser plasma sources a tangible reality for scientific and societal applications. The main short-term goals that emerged from the discussions were: reliable and reproducible targetry systems, high repetition rate (10 Hz to 1 kHz) refreshment of targets, target positioning with high precision (micron level and below), high density jet and liquid targetry, efficient management of debris and minimisation of contamination.

In addition, the participants agreed on the creation of an international cluster to bring together the academic and industrial players from the targetry fields. Its objectives would cover the following actions: increasing the international visibility of the field, gathering experts around central issues and identifying the main barriers to broad impact applications, organising seminars and future symposiums, proposing a portal to internship offers and learning for students, collectively preparing funding applications in response to calls for targeted projects (both European and non-EU).

Finally, it was decided that the next edition, TARG3, will be held in 2016 in Salamanca (Spain), under the direction of the Cluster Board to be appointed and a local organizing committee.

**François Sylla (SourceLAB )**

## International Training Session OPCPA

**The International Training Session on OPCPA (Optical Parametric Chirped-pulse Amplification) took place at Laserlab-Europe partner Université de Bordeaux and the Pyla training centre of the Institut d'Optique d'Aquitaine on 19-21 January 2015. The training session was attended by 33 people.**

The objectives of the training session were to provide basic knowledge in both linear and non-linear optics, to understand the parametric process, to learn how to simulate and design the various stages involved in parametric amplification (SHG, OPO, OPA, OPCPA) and to present state-of-the art OPA and OPCPA devices. In addition, the training session meant to foster a network at the national and international level, as well as to facilitate the exchange of knowledge and to share know-how between the attendees, and to trigger collaborations.

In order to fulfil the last three objectives mentioned above, the missions and the actions of the Laserlab-Europe and FEMTO networks (partners and co-funders of the OPCPA training) were presented by Eric Cormier and Guy Buntinx (coordinator of the FEMTO network), respectively.

The training session was organized on a three-day schedule. The first day was dedicated to basics in linear and nonlinear optics, the fundamental principles of parametric amplifier architectures, properties of linear and nonlinear optical materials and crystals used in different architectures and at different wavelength range of interest. The first day was concluded by an introduction and review of numerical simulation methods (in connection with the computer session).

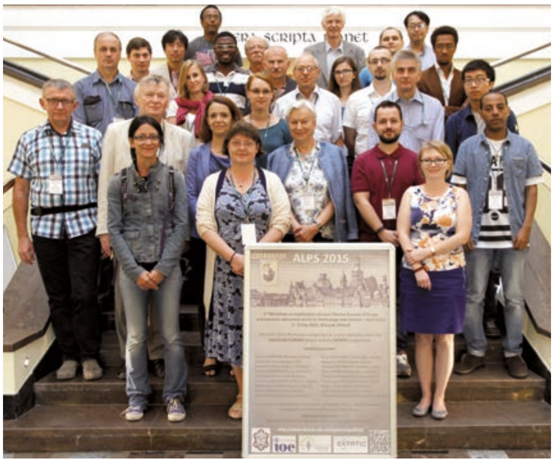
In addition to lectures and scientific presentations, the session offered practical training. The presence of trainers in theoretical courses also helped to ensure coherence and efficiency in the continuity of the first two days of training.

The second day of training was devoted to presentations (30-minute lectures) of practical realisation of OPCPA systems. The 11 presentations were intended to cover the broadest and most representative overview of technologies, materials, architectures, energy, pulse durations and wavelength available.

The third day was devoted to practical work. In order to ensure the best conditions for this session, enrolment was limited to 25 participants. The group was split to work at four workstations, instructed and supervised by five trainers and a technician. The proposed activities were: frequency doubling, numerical simulation, Kerr effect and continuum generation, and parametric amplification.

During these three days of training, several opportunities (coffee break, lunch) were provided to help creating contacts between participants and trainers.

**Sonia Geay,**
**Jean-Christophe Delagnes,**
**Eric Cormier (CELIA)**




## ALPS 2015: Application of Laser Plasma Sources of X-rays and Extreme Ultraviolet (EUV)

**The 1st Workshop on Application of Laser Plasma X-ray and EUV Sources in Technology and Science (ALPS 2015) was organized from 6 to 9 July in Warsaw as a joint initiative of Laserlab-Europe and the EXTATIC programme. Development and application of laser-driven secondary sources, including sources of X-rays and extreme ultraviolet (EUV) is one of the main topics addressed in Laserlab-Europe. EXTATIC is an Erasmus Mundus Joint Doctorate programme of the European Union that offers high-level training in extreme ultraviolet (EUV) and X-ray science (www.extatic.eu).**

The aim of the ALPS 2015 Workshop was to provide an international forum for the doctoral candidates and post-docs participating in Laserlab-Europe and EXTATIC involved in the research on application of laser plasma sources of X-rays and EUV in various fields of technology and science, including nanolithography, micro- and nanoprocessing of materials, modification of polymers for biocompatibility control, radiation damage of solids, imaging of nanostructures, microradiography and tomography, radiobiology, photoionization of small quantum systems, etc. The practical application of laser plasma sources of X-rays and EUV that are developed in Laserlab-Europe and demonstration of their capabilities and suitability for potential users were the main technical issues considered and discussed.

More than 40 participants from 11 countries took part in the workshop. During ten plenary sessions 18 introductory lectures were given by invited experienced scientists, while the same number of oral presentations was given by early-stage researchers and doctoral candidates, mainly from the EXTATIC programme, who reported results of their investigations using the laser plasma sources.

The ALPS 2015 Workshop was organized by the Laser-Matter Interaction research group at MUT-IOE, which participates both in Laserlab-Europe and the EXTATIC programme. It was the first scientific and technical meeting dedicated to applications of laser plasma X-ray and EUV sources in various fields and we believe that it started a regular series of workshop on this subject.

**Henryk Fiedorowicz (MUT-IOE)**

## User Workshop on Light-based Technologies in Trnava

**The Workshop on Light-based Technologies was held in Trnava, Slovakia on 2-4 September 2015 in the framework of the Laserlab-Europe User Community Training schools for potential users. The workshop was designed to attract new users who are not specialized in these technologies, but who have the potential to use light-based technologies in their work: Ph.D. students and research assistants in organic and inorganic chemistry, material and sensor sciences, and biomedicine.**

The workshop brought together an interested international group of young scientists who mostly participated in a Laserlab Training School for the first time. The training school was organised by the International Laser Center (ILC) in collaboration with University of Ss. Cyril and Methodius (UCM) in Trnava that provided the premises for the whole workshop. The programme was attended by sixty participants – including sixteen speakers and six company representatives – from eight different countries.

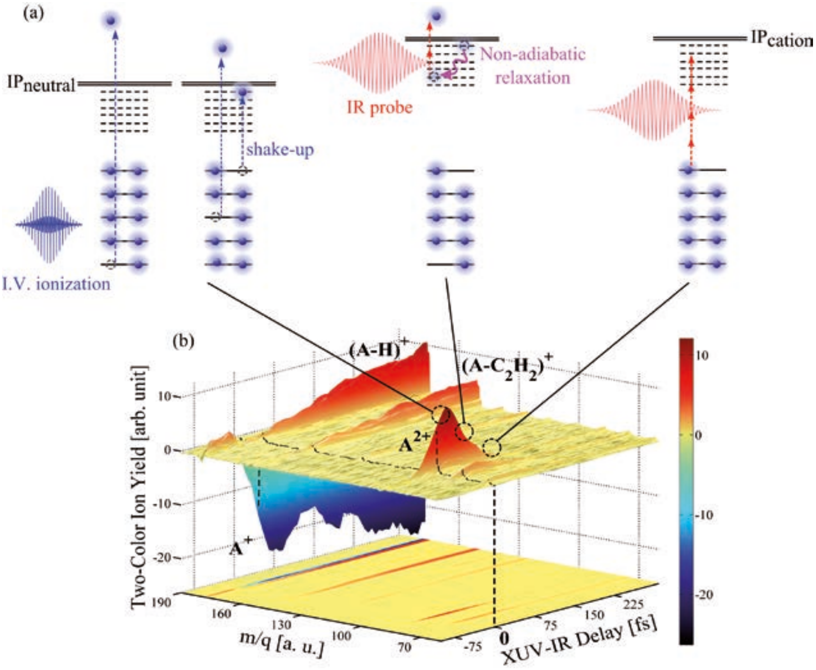
In the afternoons of the second and third day of the workshop, five laboratory hands-on trainings were offered at UCM. Participants were divided into five groups, each group spending an hour at each location. The hands-on trainings were preceded by company presentations of the setups that included a Carl Zeiss fluorescence microscope, a time-resolved ILC setup from Becker & Hickl, light spectrometry, and 3D printing. The last hands-on training aimed at improving academic writing skills.

In the evening, three parallel sessions were organised. The first session focused on academic writing and research study protocol preparation, the second consisted of a panel discussion on careers in light-based technologies with emphasis on Marie-Curie fellowships, SPIE student chapters, and the ELI infrastructure in Hungary. The third session addressed application possibilities for Laserlab facilities and the Year of Light activities in Slovakia and abroad.

**Alzbeta Marcek Chorvatova (ILC)**

# Ultrafast XUV-induced processes to comprehend the molecular complexity of the universe

For our understanding of how chemical complexity appears, leading to biomolecules and ultimately life, knowledge of the molecular composition of interstellar media is essential. In a recent transnational access project performed at the XUV-IR pump-probe beamline of the Max Born Institute (MBI, Berlin), an international team led by Franck Lépine from CNRS has shown that polycyclic aromatic hydrocarbons (PAHs) could very well be carriers of diffuse interstellar bands (DIBs). The results were published in Nature Communications.




*(a) Schematic of the XUV-induced dynamics in PAH molecules. (b) Two-colour XUV þ IR ion signals measured in the case of anthracene, as a function of the detected mass-to-charge ratio and the XUV-IR delay. Reproduced from A. Marciniak et al. Nature communications 6, 7909 (2015).*

Molecular spectroscopists have made major efforts to identify small molecules with the help of laboratory experiments, which allowed them to find their signatures in emission and absorption spectra measured by telescopes. Today, several hundreds of small molecular species have been clearly identified, proving that our interstellar environment has a rich molecular composition.

However, there remains a crucial step in the comprehension of this abundance that concerns the identification of large species that are intermediates to biomolecules. The identification of large species in the "molecular universe"[1] is indeed a major bottleneck in astrochemistry, where spectral signatures are less evident and for which experimental and theoretical tools of molecular spectroscopy are less developed. At the centre of this question is the interpretation of the so called "Diffuse Interstellar Bands" (DIBs), a series of 400 broad absorption bands in the visible-UV domain measured by telescopes. These bands are often considered as a spectral signature of complex molecular structures that have high absorption efficiency and short excited states lifetimes in the range of few tens of femtoseconds to picoseconds.

Among the possible carriers of these bands, carbon-based molecular structures such as fullerenes and polycyclic aromatic hydrocarbons (PAHs) appear as good candidates. Fullerenes as DIBs carriers have been potentially identified very recently[2], but they correspond to a "dead-end" of the chemical evolution in space as their stability would not allow further evolution. On the contrary, PAH molecules could be intermediates towards biomolecules and responsible for the presence of molecular hydrogen in interstellar media and for some of the DIBs.

Although very seducing, the idea that PAHs are carriers of the famous DIBs, and thus at the heart of the molecular complexity of our universe, has not been proven. One of the arguments against the PAH is the fact that for such complex molecules the lifetime of the excited states would not match the astrophysical observations. Indeed, absorbed energy can be released on short time scales through non-radiative decay mechanisms involving the coupling between electronic and nuclear degrees of freedom. Common intuition tells that excited states decay increasingly rapidly for higher photon energy and for larger systems, simply because of increasing density of states. Therefore, the mystery remains whether or not PAHs are relevant.

Although several spectroscopic methods have been used to improve our knowledge about PAHs, it is difficult for instance to produce and to perform sophisticated measurements on large cationic PAHs, while those are among the best candidates.

In our Laserlab access project, we have developed the idea that short XUV pulses could be very useful tools to investigate the properties of excited cationic species in connection to astrochemistry[3]. Indeed, starting with a neutral system that can be easily produced in the gas phase, the XUV excitation leads to ionisation and excitation of the molecule, creating "in-situ" excited cations in the interaction region, available for further experimenta-

1 A. Tielens, Reviews of Modern Physics 85, 1021 (2013)

2 E.K. Campbell et al., Nature 523, 322 (2015)

3 A. Marciniak et al., Nature communications 6, 7909 (2015)

tion. In our experiment, the ultrafast dynamics of these excited species was followed in real time by using a time delayed short IR pulse.

Because the ejected electron carries a large part of the photon energy, the XUV pump pulse creates electronically excited cations with internal energy that can reach up to 10 eV. Because electronic states are mixed-up due to the couplings with vibrational degrees of freedom, the electronic energy is progressively released into vibrational motion. This is a consequence of the breakdown of the Born-Oppenheimer approximation that is also responsible for the photostability of DNA bases. This relaxation is probed by further ionising the cations with the IR probe pulse leading to dications. The efficiency of this second ionisation step depends on the population of the electronic states: when the energy is progressively released, the ionisation efficiency decreases. Consequently, the time variation of the dicationic yield leads to a direct measurement of the lifetime of the excited cations.

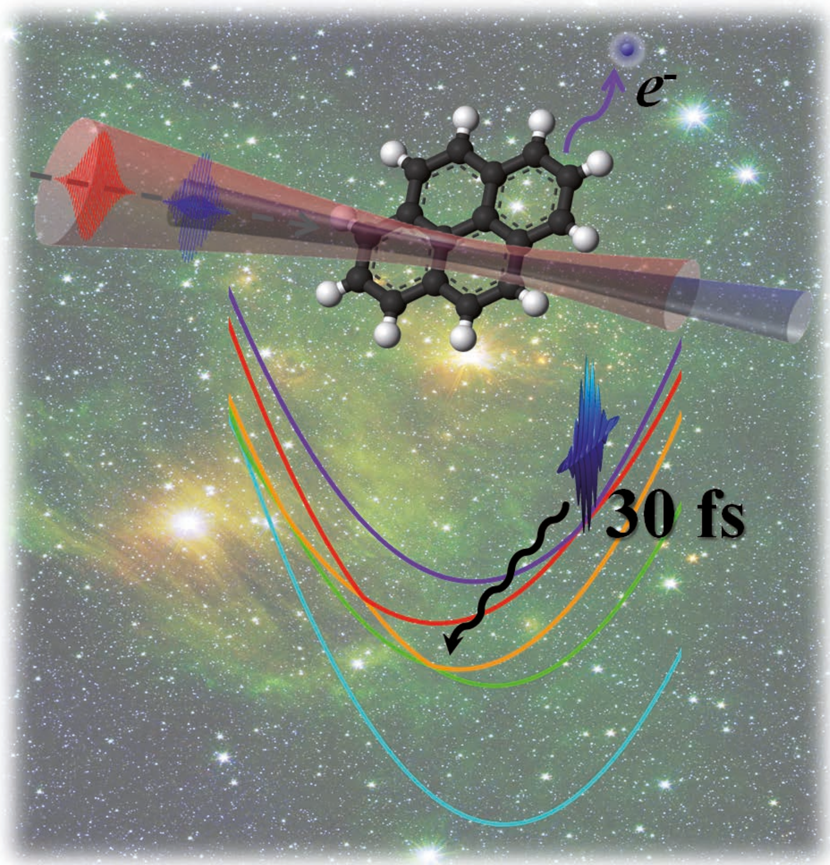
We have performed such measurements on small and large PAH (naphtalene, anthracene, pyrene, tetracene), showing that the lifetime is 25 fs for the smallest PAH composed of two carbon rings (naphalene), and slightly increases towards longer timescale up to 50 fs for tetracene (four carbon rings). These lifetimes allow us to predict that large cationic excited states might have lifetimes indeed compatible with the DIBs properties.

We have shown that short XUV pulses are very relevant when one wants to understand molecular processes in the context of astrochemistry. Moreover, it is also of prior importance to understand the quantum behaviour of molecules in a case where both independent electron picture and Born-Oppenheimer approximation are not valid. In that case the molecule is described by a complex single wavefunction describing all particles constituting the molecule. However, XUV induced ultrafast processes in molecules is still at its infancy and these experiments have been so far limited to small molecular systems such as $H_2$, $N_2$ or $NO_2$. Our experiment is therefore the first of its kind that tries to investigate large systems (composed of several tens of atoms) using short XUV pulses. It reveals the role played by multi-electronic and post-Born Oppenheimer behaviour in complex systems on a very short time scale.

To perform this investigation we have brought together a team of theoreticians from Heidelberg and Hyderabad, specialists of many-body theories, and astrochemists from Leiden, specialists of the question of the molecular complexity of the universe. The experiment was performed at the Max Born Institute as a collaborative experimental effort on the XUV-IR pump-probe beamline. We have installed our PAH source, which allowed the production of a high-density PAH beam at the laser interaction region. The beamline delivered stable, well-characterised short XUV pulses (35 fs) in the spectral region of 20 eV, this pulse was recombined with a 30 fs IR pulse at weak intensity. Stability, photon flux and well-characterisation pulses were crucial ingredients for the success of the experiment and the understanding of the results.

Ultrafast mechanisms are crucial missing information in our quest to improve our understanding of the molecular complexity in interstellar media. This could change our current description of molecular processes and contribute to our understanding of DIBs, of the production of molecular hydrogen, and the role of "direct" dissociation processes. These aspects are currently under investigation in our laboratory.

**Franck Lépine**




*Artistic interpretation of the experiment. © CNRS/ILM*

# ELITRANS: creating the first truly international laser facility

**In order to have the Extreme Light Infrastructure (ELI) operate as a single, distributed international user facility of pan-European dimension by 2018, the ELITRANS project aims to create a business model and business plan for the future international consortium ELI-ERIC, into which the current national pillars of ELI in Romania, Hungary, and the Czech Republic will be merged.**

Since ELI first appeared on the ESFRI Roadmap 2006, the project has transformed from a single-sited user facility towards an ensemble of complementary infrastructures under national responsibility of the three Central European host countries within the ERDF frame, in order to be eligible for EU Structural Funds for construction of the sites. Now it is time to manage the back-transformation into a single legal entity, ELI-ERIC, for the operation phase due to start in 2018. The project ELITRANS should yield a business model and business plan for ELI-ERIC, and steps will be taken towards unification of ELI's internal structures and procedures, an internal corporate identity, a common scientific profile, and competitive user research opportunities. To these ends, user-facility interfaces will be standardised, health and safety regulations will be defined, and computing and big data management issues will be addressed.

# EUCALL: building bridges between major laser and X-ray research centres

**In recent years, new developments have enhanced the generation of X-rays at large-scale optical laser and accelerator facilities, requiring large international research centres. The European Union is now funding a 7 million euro effort to bring these research centres together through the European Cluster of Advanced Laser Light Sources (EUCALL) project. The project will be managed by European XFEL, an X-ray free-electron laser currently under construction in the Hamburg area of Germany, where a kick-off meeting was held on 29-30 October 2015.**

Three major international research infrastructures have a key role in EUCALL: European XFEL, a 3.4 km-long X-ray free-electron laser that will open in 2017 and use ultrabright X-ray laser flashes to investigate nanoscale particles, ultrafast processes, and extreme states of matter; the European Synchrotron Radiation Facility (ESRF) in Grenoble, France, which is one of the most prominent X-ray research centres in the world, and the Extreme Light Infrastructure (ELI). Also involved are five other institutes: DESY, which operates the FLASH and PETRA III X-ray user facilities, in Hamburg, Germany; ELETTRA, which operates the FERMI free-electron laser, in Trieste, Italy; Helmholtz Zentrum Dresden-Rossendorf, which operates high-power optical laser facilities and a free-electron laser, in Germany; Lund University, which is building the MAX-IV synchrotron, in Sweden; and the Paul Scherrer Institut, which is building the SwissFEL X-ray free-electron laser, in Villigen, Switzerland. In addition, Laserlab-Europe and FELs of Europe participate in the project, representing the EU networks of optical laser- and accelerator-based X-ray laboratories.

Within the EUCALL project, the two types of large-scale X-ray RIs in Europe collaborate for the first time in a comprehensive way on technical, scientific, and strategic issues. One of the project's main goals is to make substantial scientific and technological contributions by creating and exploiting synergies between laser-driven and accelerator-driven X-ray RIs.

## Forthcoming events

**Joint JRA Meeting**
24-25 November 2015, Milano, Italy

**NAUUL Meeting**
30 November 2015, Salamanca, Spain

**Science@FELs 2016**
Fall 2016, Trieste, Italy

*To find out more about conferences and events, visit the Laserlab online conference calendar.*

## 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 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 Access Selection Panel (ASP) of Laserlab-Europe. The ASP sends the proposal to external referees, who will judge the scientific content of the project and report their judgement to the ASP. The ASP will then take a final decision. In case the proposal is accepted the host institution will instruct the applicant about further procedures.

## Laserlab Forum Contact:

Professor Claes-Göran Wahlström
Coordinator – Laserlab-Europe
The Coordinator's Office
Daniela Stozno
Assistant to the Coordinator
Max Born Institute
Max-Born-Str. 2A | 12489 Berlin | Germany
Phone: +49 30 6392 1508
Email: *stozno@mbi-berlin.de*

**Editorial Team:**
Tom Jeltes (*tomjeltes@gmail.com*)
Julia Michel, Daniela Stozno
Layout: unicom Werbeagentur GmbH

If you would like to subscribe to this publication or find out more about the articles in this newsletter, please contact the editorial team at *office@laserlab-europe.eu*

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