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Laserlab-Europe Newsletter

The present document combines the fourth and fifth issue of the Laserlab Newsletter that were published since the start of the project. Instead of publishing only one issue per year electronically and in print as foreseen according to the grant agreement, Laserlab-Europe continues to publish the newsletter on a biannual basis. This highly appreciated newsletter has been started in FP6 with consecutive numbering, so that the issue numbers in this document are nos. 17 and 18.

Issue 17 of the Laserlab-Europe newsletter: June 2014 (M25);
    Focus: 'Lasers for Life': examples of laser research and applications in several areas of medical science

Issue 18 of the Laserlab-Europe newsletter: December 2014 (M31);
    Focus: 'Lasers for Solar Energy': developments in solar technologies studied with laser science

All issues of the newsletter "Laserlab Forum" may be found at:

http://www.laserlab-europe.eu/news-and-press

Issue 17 | June 2014

Laserlab Europe

Laserlab Forum

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

Lasers for Life

Emma Springate (CLF) operating the ARPES end-station at Artemis. © Monty Rakusen

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In this Issue

Editorial

Tom Jeltes

For most people, the term 'Lasers for Life' will bring to mind only the well-known laser eye surgery, a set of established clinical techniques that have improved the sight of countless people worldwide. Lasers are regularly applied, however, in many other areas of medical science as well. And the global medical laser systems market is growing rapidly, with a predicted size of over €6 billion by 2017.

In order to support these amazing developments, a lot of pioneering experimental work still has to be done. Several research groups from Laserlab-Europe partners are currently working on various possible medical applications of laser light that might just become as commonplace in a clinical setting as laser eye surgery is today.

On the occasion of the Laserlab Foresight Workshop entitled 'Lasers for Life', this issue of Laserlab Forum features a Focus section in which our researchers describe their promising attempts to use lasers for such different purposes as the generation of protons for radiation therapy, imaging of live brain tissue, assessment of breasts to find tumours, and real-time non-invasive monitoring of gases inside premature babies' lungs and intestines. At a more fundamental level, techniques to monitor single biomolecules are presented. And, according to another contribution, even the abovementioned laser eye surgery could perform much better if only the optimum laser wavelength were chosen.

In this issue we also present three Laserlab scientists who obtained a Consolidator Grant, a brand new grant from the European Research Council, situated right in between the familiar Starting and Advanced Grants. And we have a rather special Access Highlight contributed by Emma Springate from the UK's Central Laser Facility, which shows how their Artemis facility is used by two competing groups of scientists to reveal the intriguing and possibly very useful properties of the Nobel Prize winning material graphene.

But, to come back to the main theme of this issue of Laserlab Forum: even the news items on the following pages will give you an impression of how intimately laser science and life science have become intertwined, demonstrating the healing power of laser light.

Tom Jeltes

News

BabyLux: supporting pre-term babies

Laserlab-Europe partners ICFO (Barcelona) and CUSBO (Milan) are leading a new European project, called 'BabyLux', which aims to provide support for vulnerable babies by developing an optical device to monitor the blood and oxygen flow in critically ill newborns. The BabyLux project has a budget of €4 million and should lead to a device which will be tested already in 2014-2015.

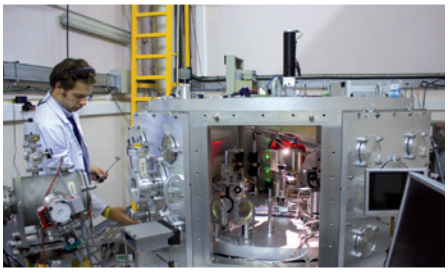
Pre-term births have risen by twenty percent in the West in the past two decades and currently account for a significant portion of children with cerebral palsy and cognitive, visual and hearing impairments. These are the result of brain damage due to lack of blood flow and oxygen delivery during the early stages of brain development. The Medical Optics Group at ICFO, led by Prof. Turgut Durduran, has already developed and tested a prototype for monitoring blood flow and oxygen levels in adult patients using lasers. This technology is being commercialised by Hemophotonics, an ICFO spin-off company also involved in the BabyLux project.

Laser system to fight cancer installed at LOA

Early 2014, a dedicated laser system for cancer radiation therapy was commissioned at Laserlab-Europe partner LOA in Palaiseau, France. The 200 TW ultrafast laser and experimental beamline is part of the French SAPHIR project in which LOA participates.

Protons generated from lasers form an alternative to the classical particle acceleration techniques that are used for cancer treatment. SAPHIR, a French project with involvement of Laserlab-Europe partners LOA and SLIC, has been launched a few years ago to determine the technical and economic viability of laser proton therapy. The final goal of the project is to realise a working prototype able to produce ions of medical interest and to prove their efficacy onto biological samples. SAPHIR is coordinated by the company Amplitude Technologies, and largely funded by the investment organisation Oséo.

During the next few months several new strategies for laser-ion acceleration will be explored and tested, with a full characterization of the beam parameters (energy, charge, diver-



Experimental chamber of the SAPHIR project used to generate protons from femtosecond intense laser systems.

What is Laserlab-Europe?

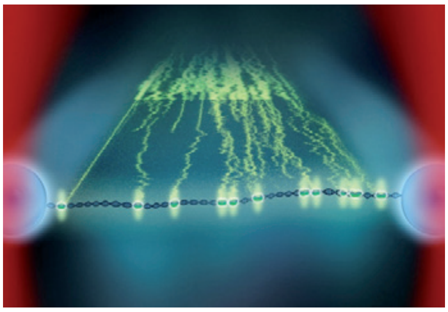
Laserlab-Europe, the Integrated Initiative of European Laser Research Infrastructures, understands itself as the central place in Europe where new developments in laser research will take place in a flexible and co-ordinated fashion beyond the potential of a national scale. The Consortium currently brings 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.

gence). In-vitro and in-vivo experiments will be carried out in the various explored conditions, in order to observe the biological effects induced by laser particle beams, which can reach peak dose rates higher than conventional accelerators. The SAPHIR project should lead to the design of machines that are advantageous in terms of cost, weight, compactness and flexibility, and could be installed in hospitals.

Filming the crowd on DNA

Researchers of LaserLaB Amsterdam (Wuite and Peterman labs, VU University) have developed a new method to study protein dynamics on densely covered DNA *in vitro*. Their work recently featured on the cover of the journal Nature Methods.

Cellular DNA is ubiquitously covered by a high density of proteins. Such high density leads to low accessibility, which has a large impact on processes such as DNA repair and gene expression. The approach Iddo Heller and his co-workers at LaserLaB Amsterdam used to study this crowded molecular dance is based on optical tweezers, an established single-molecule technique that was used to stretch DNA and probe how its mechanical properties are affected by biomolecular processing. Concurrently, the researchers used super-resolution fluorescence microscopy to visualise protein



Artist's impression of proteins on DNA (illustration: Ivo van der Ent). The DNA is stretched between two microspheres (blue) that are held in focused trapping lasers (red). The protein trajectories (green) along the DNA are shown fading toward the background. STED nanoscopy (foreground trajectories) provides a 6-fold resolution enhancement over confocal imaging (background trajectories).

binding, diffusion, and enzymatic activity on the optically stretched DNA.

A spin-off company, LUMICKS, has now been founded to make this type of correlative optical tweezers technology available to a wide range of biological and biomedical scientists. Widespread experimental access to biologically relevant protein densities is essential for linking idealised *in vitro* experiments with the *in vivo* situation of DNA in cells. Additionally, this new technology can provide biomedically more relevant insight into (dys)functional DNA-protein interactions.

CLF spinout's airport laser scanner nominated for prestigious engineering award

© Cobalt Light Systems

The nominated team with the airport laser scanner: P. Matousek, G. Maskall, S. Bonthron, C. Tombling, P. Loeffen.

A security scanner developed by Central Laser Facility spinout Cobalt Light Systems is one of three candidates announced to be in the running to win the UK's premier engineering prize, the MacRobert Award, alongside Rolls Royce and QineticQ-owned Optasense.

The technique that lies behind Cobalt's innovation, known as Spatially Offset Raman Spectroscopy (SORS), was invented by the CLF's Professor Pavel Matousek. Using SORS, the content spectrum of a plastic bottle can be measured without knowing the bottle material or its relative signal contribution. SORS can also be applied to other systems, including biological ones, and was part of the Laserlab-Europe Joint Research Activity Optbio.

Cobalt Light Systems developed an airport security scanner that should enable airports to remove the existing hand-luggage liquid ban through phased implementation over the next few years in response to regulation. The system is now operational in 65 airports across Europe following new regulations introduced in January 2014. The fundamental science behind the device could also be used for non-invasive cancer screening, detecting counterfeit goods, and food analysis in the future.

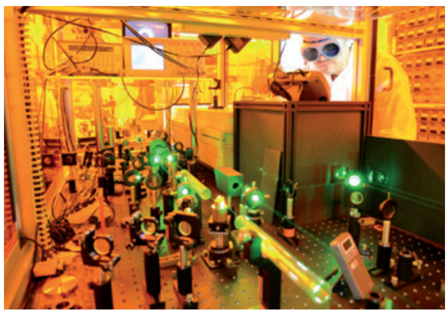
The Royal Academy of Engineering MacRobert Award is the UK's longest running national prize for engineering. It identifies outstanding innovation with proven commercial promise and tangible societal benefit. It comprises a £50,000 cash prize and a gold medal.

L2I gets green light for roadmap

The Laboratory for Intense Lasers (L2I), located at Laserlab-Europe partner IST, Lisbon, was selected for the Portuguese Roadmap of Research Infrastructures in a recent call by FCT, the Portuguese Foundation for Science and Technology.

L2I hosts the most powerful laser in Portugal. FTC classified the facility in the top category: 'those that have demonstrated high scientific potential and are considered to have high strategic regional and/or national relevance', and it recommended the establishment of a distributed infrastructure with Coimbra Laser Lab, subcontractor of Laserlab-Europe.

Through the National Roadmap of Research Infrastructures, FCT envisages to support research infrastructures of strategic interest, to underpin scientific and technological advances and bolster the capacity of the R&D community in Portugal to be an active member of European and international projects.



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ERC Consolidator Grants

Since 2013, the European Research Council (ERC) has a new funding scheme: the Consolidator Grant. The new grant is meant for independent researchers with between 7 and 12 years experience after their PhD. The Consolidator Grant thus partially replaces the existing ERC Starting Grant, for which scientists with up to 12 years' experience were eligible. It provides funding of up to €2.75 million per grant for a maximum of 5 years. Out of 312 mid-career top researchers who have been awarded a Consolidator Grant, three are Laserlab-Europe scientists: Davide Iannuzzi from LaserLaB Amsterdam, Antonio Acín from ICFO, Barcelona, and Jens Limpert from the Friedrich Schiller University in Jena.

Davide Iannuzzi

Davide Iannuzzi: Micromachined optomechanical devices (DIDYMUS)

The project of Davide Iannuzzi, University Research Chair professor at LaserLaB Amsterdam, builds upon his 'fibre-top'-technology, which allows producing an atomic force microscope probe at the end of an optical fibre. In three ambitious research lines, he intends to combine the senses of 'sight' (optics) and 'touch' (mechanics) in three different optomechanical instruments that should allow him to tackle unanswered questions on each of the three most relevant scales in life sciences: cells, tissues, and organs.

The first project entails designing and testing a new optomechanical probe to investigate how a sustained mechanical load on a brain cell of a living animal may trigger changes in its central nervous system. In the second project, an optomechanical tactile instrument will be developed in order to assess how subsurface tissues deform in response to a mechanical stroke. The last research project aims at delivering an acousto-optical gas trace sensor, which should be so compact that it can be used inside lungs to find early signs of life threatening pulmonary diseases.

Antonio Acín

Antonio Acín: Quantum information theory with black boxes (QITBOX)

Looking for ways to exploit the extraordinary potential of quantum information, scientists are currently developing all kinds of different quantum systems. In his Consolidator Grant project, Antonio Acín, ICREA Professor at ICFO, will try to develop a theoretical framework that should allow him to understand what can and what cannot be done with these quantum systems in terms of information processing. In this framework, the quantum systems are seen as 'black boxes' – their only relevant properties are the input they receive and the output they produce.

Acín will first characterise the correlations that are possible among quantum devices. These correlations will subsequently be used to construct relevant information protocols, which will finally be applied to concrete physical setups – such as quantum-optical systems. The idea is that, based on the identified correlations, new methods can be developed to study many-body systems.

Jens Limpert

Jens Limpert: Advanced Coherent Ultrafast Laser Pulse Stacking (ACOPS)

In the future, cheap and compact particle accelerators for collider experiments and cancer treatment might be based on laser technology. In laser wake-field particle accelerators, ultra-short and high-power laser pulses are used to create electron waves in a plasma, producing electric forces by which electrons or protons are accelerated to almost the speed of light. Such laser accelerators, however, require laser systems that combine high peak power laser pulses with a large number of pulses per unit time – a high repetition rate.

In his Consolidator Grant project, Jens Limpert, Junior Professor at the Friedrich Schiller University in Jena, is planning to apply a technique called coherent pulse stacking in order to create a laser system that produces laser pulses with an energy of 32 J at a repetition rate as high as 15 kHz – numbers that are far beyond the state of the art. To this aim, he will try not only to coherently combine laser pulses from several fiber amplifiers, but he also plans to temporally store laser pulses inside optical cavities – waiting to be released as a coherent pulse train when a sufficient number of laser pulses have been built up inside.

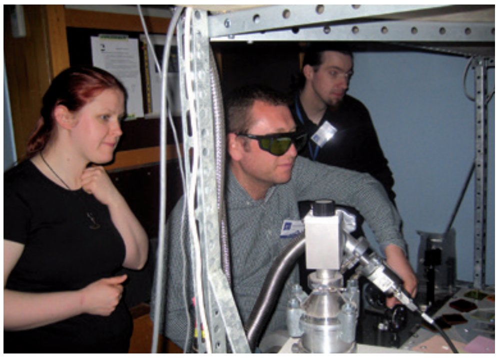
Laserlab User Training School in Riga

A Laserlab-Europe Training School for Potential Users was held in Riga, Latvia from April 9 to 12, 2014. It was organised in concert with the tenth annual Developments in Optics and Communications (DOC) conference for young scientists, sponsored by the local student chapters of the Optical Society of America (OSA) and SPIE, in order to take advantage of the synergy between the two events.

Spring had not quite reached this beautiful city on the shore of the Baltic Sea, but that did not stop a large and very international group of young scientists from attending. Sixty young scientists participated in the training school, and a total of 122 people took part in the combined event. Twenty countries were represented among the participants and speakers: Sweden, Denmark, Ireland, Canada, Bulgaria, Turkey, Poland, Israel, Latvia, Lithuania, Italy, the Netherlands, Hungary, the United Kingdom, Portugal, Finland, Spain, France, Slovakia, and Switzerland. The training school offered five laboratory exercises. The DOC conference featured 8 invited talks and over 35 contributed talks in the fields of laser physics and spectroscopy, optics in communication, optical materials and phenomena, biophotonics, and vision science. In addition, 48 posters were presented in the poster session on the last day.

The conference and training school talks took place at the Institute for Solid State Physics on the banks of the Daugava river. In the afternoons of April 10 and 11, laboratory exercises were offered at three locations. At the Institute for Solid State Physics, students had the opportunity to see pulsed lasers in action to study the fluorescence dynamics of rare earth elements, such as Erbium. This rare earth element is important in telecommunications applications where it appears in the erbium doped fibre amplifier. Time resolved luminescence spectra yield insights into the relaxation processes and luminescence mechanisms. Participants learned how to prepare samples, adjust the apparatus, and optimise the signals.

The biophotonics laboratory of the Institute of Atomic Physics and Spectroscopy offered a training session on how to measure the autofluorescence lifetime and photobleaching rate of skin. The skin was exposed to laser radiation from an optical fiber, and fluorescence light was collected. The skin could be excited with picosecond pulses (60 ps half-width) to measure autofluorescence lifetimes between 0.5 ns and 8 ns. Continuous radiation could be applied over several minutes to measure photobleaching by passing the fluorescence light through a spectrometer. These autofluorescence lifetimes and photobleaching rates can distinguish between malignant and benign skin lesions.



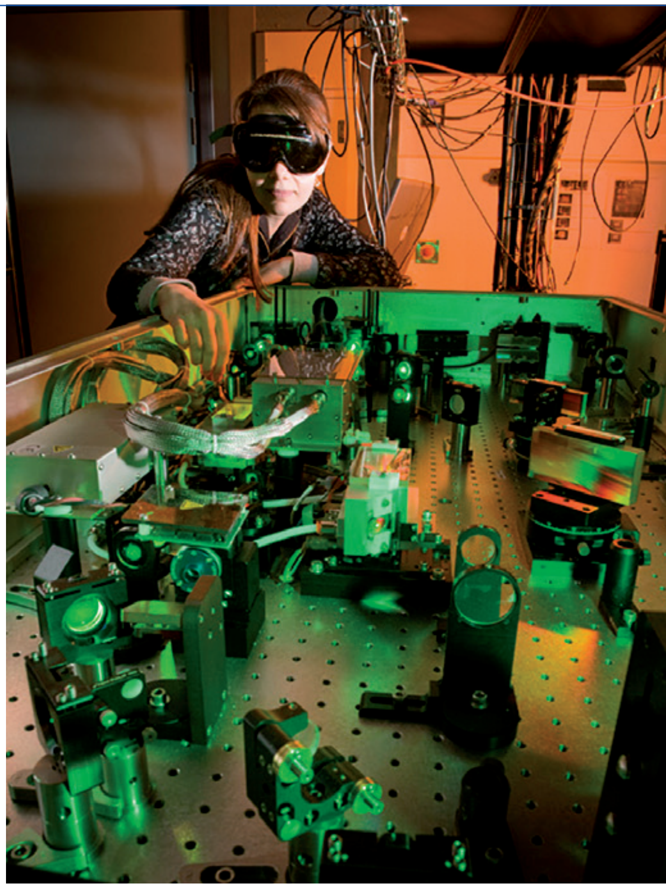
Finally, the Laser Centre of the University of Latvia, located at the Faculty for Physics and Mathematics, offered two sessions. In one session students learned about nitrogen vacancy centres in synthetic diamond. These have a triplet ground state, which can be manipulated by pulses of laser radiation and microwaves. The participants learned how to observe Rabi oscillations between the $m_s=0$ and $m_s=1$ states, and to measure the spin-lattice decay constant. In another session, trainees learned to work with a Ti:Sapphire laser system. They had to make the necessary adjustments to obtain the correct frequency. Then they aligned all components for a saturated absorption spectroscopy system and learned various practical skills, such as how to cut an optical fibre and couple light into it.

Thanks to the laser school and the conference, students had the chance to network with other young scientists from many countries and to learn about other fields of physics and new experimental techniques. All in all, it was a valuable experience, which we hope will be repeated soon.

Florian Gahbauer
(Laser Centre of the University of Latvia, ULLC)

Lasers for Life

In the past decades, lasers have found many applications in the biomedical domain, ranging from fundamental research to disease diagnosis and treatment. Laserlab-Europe is active in many areas of biomedically-related laser science, and significant advances are being made across all areas. To help set out a roadmap for the field, Laserlab-Europe is holding a 'Lasers for Life' Foresight Workshop at the Royal Society, London, from the 2nd to 4th June 2014. On the following pages, Laserlab researchers provide insight into the diverse range of biomedical topics that are addressed within the consortium, starting with an overview of the UK's Central Laser Facility, organiser of the Foresight Workshop.

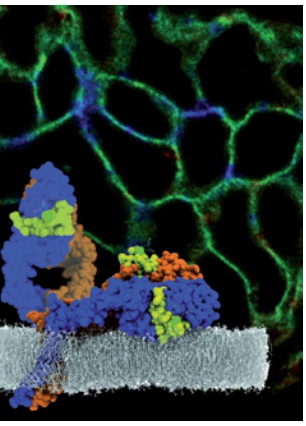


Aligning one of the Ultra laser systems.

CLF: Octopus, Ultra, and Astra Gemini

The Central Laser Facility (CLF) hosts an active programme of biomedical research supported by the FP7 Joint Research Activity BIOPTICHAL and its predecessor OPTBIO, in which several of CLF's laser facilities are used according to their various strengths.

Octopus is one of the world's largest facilities for laser-based optical microscopy, focussed on biological and medical research. An extensive range of imaging techniques including multiphoton microscopy, single molecule fluorescence imaging in cells, and several 'super-resolution' microscopes provide the biomedical researcher with a toolkit to investigate how biomolecular structure and dynamics in cells and tissues are responsible for the functioning of organisms in health and disease.



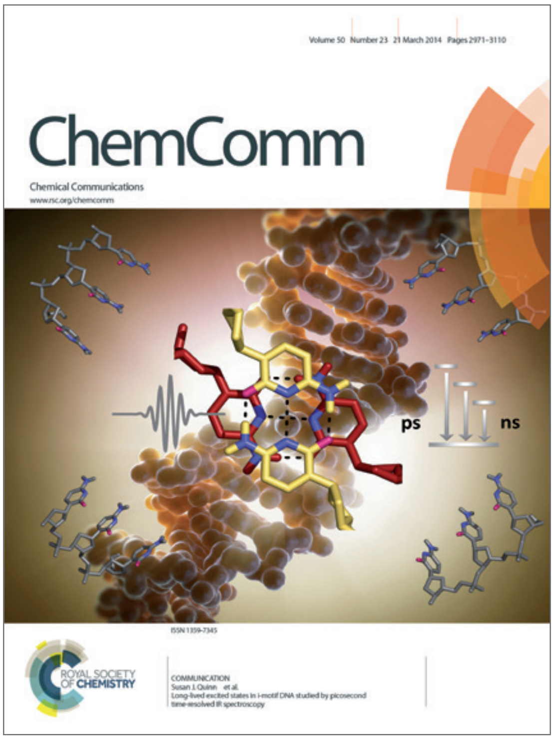
Model of epidermal growth factor receptor in cells, derived from Octopus FRET data.

For example, Marisa Martin-Fernandez from the CLF is leading a project in collaboration with cancer researchers from King's College London and a clinician from Guy's and St Thomas' Hospital, investigating the behaviour of a family of 'gatekeeper' molecules that are the targets of a number of new anti-cancer therapies. The unique combination of techniques available in *Octopus* enables the research team to study how the molecules transmit their signals to the cell, how active and inactive forms of the molecule are organised on the cell surface, and how mutations affect the signalling process. A collaboration with a drug development company is providing fluorescent derivatives of anti-cancer drugs so that their effect on the signalling molecules can be monitored. Ultimately, the goal of this research is to direct 'targeted therapeutics' by obtaining a molecular fingerprint from tumour biopsies, that can be used to ensure the patient receives the best treatment. This work is funded by the UK's Biotechnology and Biological Sciences Research Council (BBSRC).

Octopus is also in demand from European users, with Laserlab-Europe recently funding access for groups working on advanced tracking of biological molecules in cells, plant biology, and DNA damage.

The CLF's *Ultra* facility is the world's most sensitive time-resolved vibrational spectrometer, and in a similar way to *Octopus* offers multiple experimental stations linked to a suite of advanced lasers. The spectroscopic techniques offered are suitable for the study of the dynamics of molecules on timescales from femtoseconds to milliseconds. *Ultra* was partially funded by BBSRC with the specific aim of applying its unique capabilities to the investigation of biological molecules.

Laserlab-Europe has funded a number of visits to *Ultra* by Susan Quinn from University College Dublin. Dr Quinn is interested in the properties of DNA, and has used *Ultra* to investigate the photophysics of biologically relevant conformations of DNA, implicated in the mechanisms underlying photodamage. This work was recently published



Long-lived excited states in i-motif DNA studied by picosecond time-resolved IR spectroscopy.

in *Chemical* Communications, in which it featured on the front cover. She has also used *Ultra* to investigate the interaction of DNA with carbon nanotubes and nanoparticles.

The CLF's *Astra Gemini* facility is a high power, high repetition rate laser with two beams, each delivering 15 joules to target in a pulse of 30 femtoseconds (i.e. a peak power of 0.5 PW), with a repetition rate of one shot every 20 seconds. Although the facility has been targeted at ultra-high intensity physics research, it is now finding applications in biomedical imaging. The extreme acceleration of electrons in plasma to high energies (~GeV) in a short distance (~1cm) has long been a focus of intense laser research. In recent years researchers have been looking more closely at the x-ray emission that accompanies this acceleration as the electrons wiggle in the strong transverse forces in the plasma. Because of its short pulse duration (~few fs), the single shot (peak) brightness of this source is on a par with the average brightness of synchrotron sources. The spatial coherence guaranteed by the small source size of the beam (~mm) allows the acquisition of high resolution phase contrast images. An *Astra-Gemini* experiment led by the Plasma Physics group at Imperial College London has recently demonstrated the capability to image medical samples with quality comparable to the state of the art with conventional techniques.

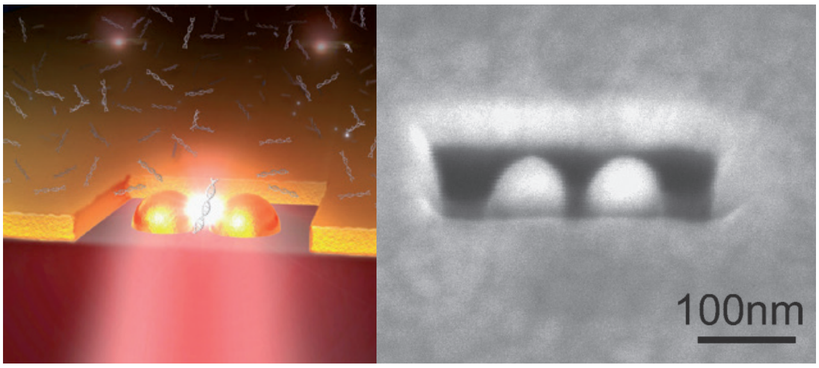
Dave Clarke (CLF)

ICFO: Biosensing of individual molecules with optical antennas

Understanding how molecules interact with each other inside the cell is key to advance our knowledge in molecular and cell biology. At ICFO, an optical device has been invented with which individual biomolecules can be detected even at the high concentrations found in living cells.

Together with the Fresnel Institute in Marseille we have conceived and fabricated the smallest optical device that can detect and sense individual biomolecules at concentrations that are similar to those found in the cellular context. The device, called 'antenna-in-a-box', consists of a tiny dimer antenna made of two gold semi-spheres and separated from each other by a gap as small as 15 nm. Light sent to this antenna is enormously amplified in the gap region, where the actual detection of the biomolecule of interest occurs. Because amplification of the light is confined to the dimensions of the gap, only molecules present in this tiny region are detected.

As an additional trick, we embed the dimer antennas inside boxes which are also of nanometric dimensions. The box screens out the unwanted contribution of millions of other surrounding molecules, reducing the background and improving the detection of individual biomolecules. When tested under different sample concentrations, this novel antenna-in-a-box device allowed for 1100-fold fluorescence brightness enhancement and detection volumes down to 58 zeptoliters (1 zL = 10^{-21}L): the smallest observation volume in the world.



Left: Artistic illustration of the antenna-in-a-box platform fabricated on gold allowing the detection of individual DNA strands at high sample concentrations. Right: Focussed ion beam image of an antenna-in-a-box as used in the experiments (© Nature Nanotechnology 8, 2013, 512-516).

Our antenna-in-a-box could be used for ultrasensitive sensing of minute amounts of molecules, becoming an exquisite early diagnosis device for biosensing of many disease markers. It could also be used as an ultra-bright optical nanosource to lighten up molecular processes in living cells and ultimately watch how individual biomolecules interact with each other, a long awaited dream of biologists.

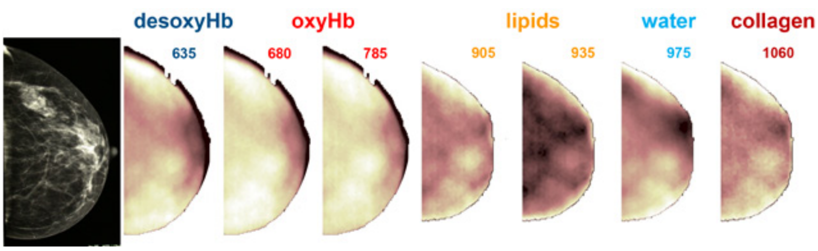
Maria Garcia-Parajo (ICFO)

CUSBO: Non-invasive optical assessment of breast density as a cancer risk factor

Breast density is well recognised as an important and independent risk factor for breast cancer. It is currently assessed through the analysis of X-ray mammographic images and is thus generally not known until the age of fifty. Within the framework of Laserlab-Europe, the CUSBO facility at Politecnico di Milano has developed a unique system for broadband time domain diffuse optical spectroscopy in the 600-1200 nm range, which can be used to measure breast density non-invasively.

Our system allows the evaluation of the average composition of biological tissues (in terms of water, lipid and collagen content) and blood parameters (total volume of hemoglobin and oxygenation level). Information is also

Left to right: x-ray mammogram and optical images at 635, 680, 785, 905, 935, 975 and 1060 nm of the left breast of a healthy subject. Above the images, the tissue constituents that mainly determine the optical behaviour at the different wavelengths are shown.



obtained on the structure of the tissue at the microscopic level. The optical measurement is completely non-invasive, painless and quick. It also provides an absolute operator-independent outcome.

A first clinical system, operated at a few discrete wavelengths yet providing also spatial information, has been developed based on the knowledge obtained by the laboratory research. The system has been used in a clinical study involving more than 200 patients, showing that optically derived parameters correlate to a high degree with both qualitative and quantitative estimates of mammographic density (i.e., BIRADS categories, typically used by clinicians, and percentage density, respectively). Recently, a dedicated portable instrument has been designed within the BIOPTICHAL Joint Research Activity and built to perform point measurements over a full spectral range (600-1200 nm).

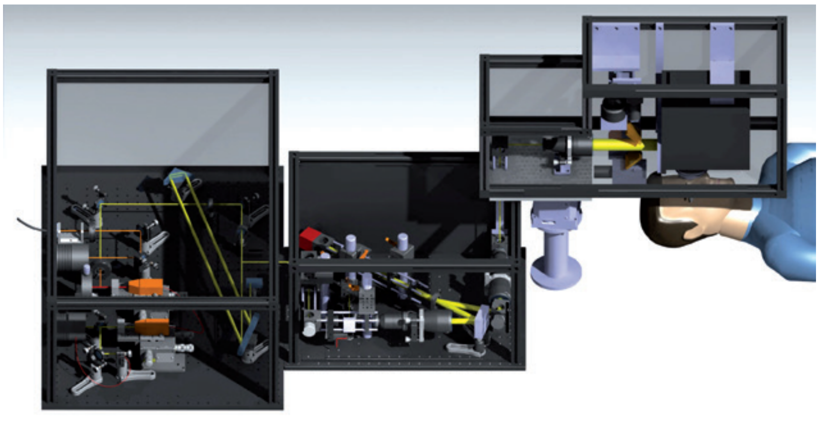
The instrumentation developed at Politecnico di Milano is unique at international level because it allows estimating the collagen content in tissue. Collagen appears to contribute fundamentally not only to breast density, but also to the origin and progression of breast cancer. Thus its estimate could provide a direct link (more direct than offered by mammographic density) with cancer risk. The impact of this pre-screening tool will be particularly significant since early diagnosis (lesion size <1cm and no lymph node involvement) leads to an impressive >90% survival rate, and great improvement in overall quality of life due to less invasive treatments.

Paola Taroni (CUSBO)

LOA: Tissue optical studies for ultra-short pulse laser surgery

The highly nonlinear and therefore strongly localised interaction process of ultra-short laser pulses with matter enables many potential clinical applications. Researchers at the Laboratoire d'Optique Appliquée (LOA) have shown that a shift of the surgical laser wavelength would lead to a significant improvement compared to current clinical laser systems.

CAD image of the demonstrator set-up of a laser surgical device for corneal grafting including a fibre laser unit (left, courtesy of Institut d'Optique Graduate School), a wavefront correction module (middle) and the beam delivery optics (right).



The first clinical ultra-short pulse laser system was commercialised with considerable commercial success in the beginning of the last decade. A number of clinical lasers are now available which provide routines for refractive and cataract surgery as well as other surgical interventions. Those systems have become increasingly widespread and produce very satisfactory results when used on transparent tissue.

However, procedures like corneal grafting need to be performed on pathological tissue, which is not perfectly transparent. In healthy cornea, the very regular arrangement of the collagen fibrils within the lamellae constituting the volume of the tissue as well as the absence of light scattering structures with micrometric dimensions are responsible for the transparency of the tissue. The transparency is lost when the regularity of the tissue structure is perturbed by pathology.

Fortunately, the light scattering processes are strongly wavelength-dependent. Our studies show the existence of a transparency window centred at about 1.65 µm even in very pathological cornea. A shift of the surgical laser wavelength from about 1 µm – which is typically used – to that window should improve the beam quality and the penetration depth considerably.

With our project partners we have developed several compact laser sources for the required wavelength range based on fibre laser technology and nonlinear optics. Our experiments on tissue show the expected results: the laser penetration depth was typically tripled and the quality of the surgical incisions was greatly improved. Interface roughness was reduced and cuts were even possible in the otherwise opaque sclera.

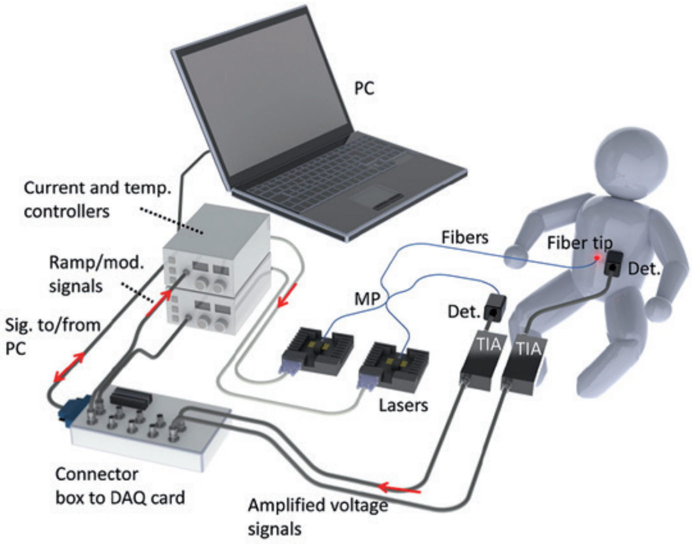
Karsten Plamann (LOA)

LLC: Optical non-invasive lung and-intestine gas monitoring in pre-term babies

Researchers at the Lund Laser Centre (LLC) are engaged in a multi-disciplinary project in which they try to measure gases inside human body cavities. The goal is to be able to continuously monitor the lung function and gas contents in the intestines of pre-term babies in a non-invasive way.

Assessing lung function is of prime importance for intensive care of pre-term children, since lack of surfactant in very premature children leads to the respiratory distress syndrome (RDS). Another severe problem for these small patients is necrotizing enterocolitis (NEC), affecting the intestines.

Following successful monitoring of gas contents in human paranasal sinuses using diode laser spectroscopy applied to scattering media (the so called GASMAS method), a feasibility study was first performed on pre-term baby thoracic phantoms. These were made up of animal lung tissue covered by gelatine layers with scattering particles and absorbing ink, mimicking the chest wall of a small child. Oxygen as well as water vapour could be detected in



Scenario for free gas monitoring in neonatal baby lungs and intestines. Single-mode diode lasers are used to observe the narrow molecular lines, which are typically 10,000 times sharper than the tissue constituent spectral features. Wavelength modulation techniques are used to isolate the gas signals. (© J. Biomed. Opt. 18, 2013, 127005)

such phantoms of realistic sizes using diode laser sources around 760 and 935 nm, respectively.

Subsequently, a pilot study on three full-term babies weighing about 4 kg demonstrated the possibility of real-world gas monitoring. An ongoing study with refined equipment on several full-term healthy babies shows promising results. Measurements on the intended target patients of weight 1-2 kg are now in planning. The hope is to develop cot-side continuous optical monitoring to replace current techniques, like occasional X-ray imaging, and to help make the start in life of these small children as good as possible.

Sune Svanberg (LLC)

LaserLaB Amsterdam: Third harmonic generation microscopy in living tissue

A major challenge in health and life science research is studying a single cell in its native three-dimensional environment of live tissue. Researchers from LaserLaB Amsterdam have demonstrated third harmonic generation (THG) to be an excellent tool for visualization of neuron morphology in living brain tissue.

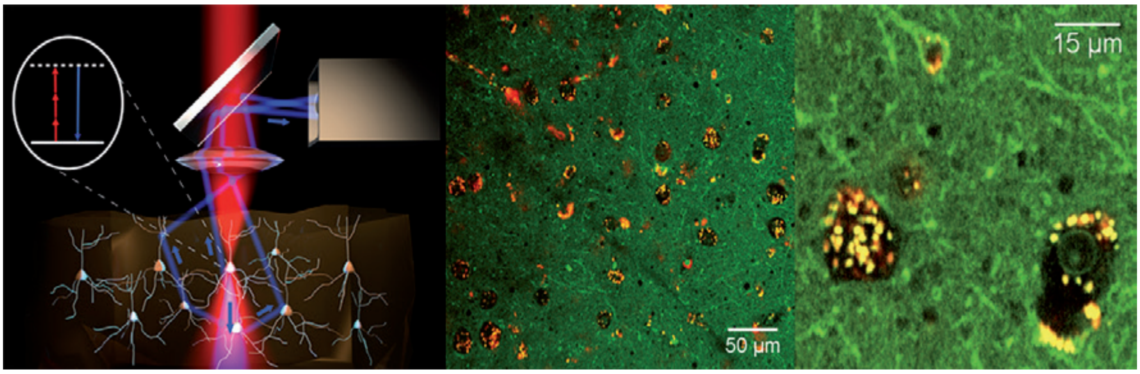
Visualization of cell dynamical processes in life tissue is of vital importance to understand the origin and progress of diseases, from the organ and tissue down to a cellular level. To enable this, tools and methods are necessary that allow observation at the sub-microscopic level, without changing or disturbing these processes. Third harmonic generation (THG) microscopy provides non-invasive, label-free contrast (that is, it needs no external contrast agents) of living tissue with sub-cellular resolution and intrinsic depth sectioning. The efficiency of THG depends mainly on the third-order susceptibility $\chi(3)$ of the medium and the phase-matching conditions.

Our group at LaserLaB Amsterdam has demonstrated THG to be an excellent tool for the label-free visualization of neuron morphology in living brain tissue. As lipids have a high $\chi(3)$ and the lipid content of the brain is high, THG is efficient. Neurons, blood vessels, astrocytes (the most abundant cells in the human brain) and axons were imaged in mouse ex-vivo brain slices, achieving near-video rate imaging of volumes of ~250x250x600 μm^3 with <0.5 μm^3 resolution.

The high-imaging speed makes THG very suitable for the study of cell dynamical processes in for example the context of neurodegenerative diseases (Alzheimer's disease, white matter diseases) or in tissue regeneration processes. Another application is in the recognition of tumour cells in the brain during a surgical resection procedure. Tissue-conserving surgery is of extreme importance in brain cancer to minimise loss of function. The major challenge of this type of surgery is the detection of tumour margins. For this purpose, a handheld THG device is now being developed at LaserLaB Amsterdam, in collaboration with the VU Medical Center.

Marloes Groot (LaserLaB Amsterdam)

Schematic representation of THG microscopy (left panel, Witte et al., PNAS 108, 2011, 5970-5975). THG images of human brain tissue, recorded at a depth 100 µm below the surface of an ex-vivo slice (middle and right panels). The neurons are visible as 'black shadows' as they produce less THG intensity than the extracellular matrix. The nucleus and nucleolus within the cells are visible. The THG signal (green) is co-collected with 2-photon fluorescence signals (red) that mainly arise from lipofuscin particles.



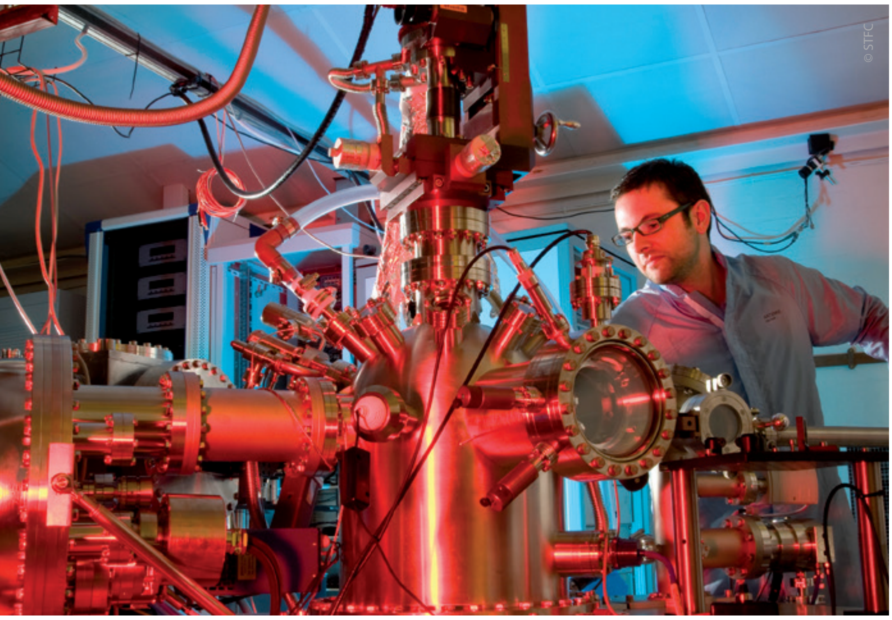
Access Highlight: Revealing the potential of graphene for solar cells, lasers and electronics

Graphene's two-dimensional honeycomb lattice is stronger than steel, lightweight, transparent and flexible, leading some to describe it as a 'miracle material' that will 'revolutionise the 21st century'. It has numerous potential applications in optoelectronic systems, such as solar cells, photodetectors and flexible displays. The key to understanding the behaviour of graphene and its suitability for these applications is to directly measure how the electrons in a graphene sheet respond to light. This has been done in two Laserlab-funded experiments at the Artemis facility that use high harmonic generation to add time-resolution to a technique commonly used on synchrotrons.

One of the palette of synchrotron techniques is angle-resolved photoemission spectroscopy (ARPES), which makes detailed static maps of electronic structure. A synchrotron beam, typically at 20-100 eV photon energy, ejects electrons from a sample using Einstein's photoelectric effect and their energies and emission angles are recorded. As the electron momentum parallel to the surface of a sample is conserved, it is possible to work back to make high-resolution maps of the electron distribution in the material.

In recent years, laser-based techniques have added time-resolution to ARPES, enabling the electronic structure to be monitored as it responds to excitation by a laser pulse. The target material is irradiated by a short laser pulse, which induces structural changes and electronic excitations. It is then probed at a series of time delays by a short wavelength pulse which generates photoelectrons that are then collected and analysed. This series of snapshots of the electron energy distribution is then sequenced into a movie of electron dynamics.

Jesse Petersen (Oxford University) operating the ARPES end-station at Artemis.



Until recently, time-resolved ARPES measurements with lasers have typically used only near UV radiation (<7 eV). The low photon energy meant that only a small subset of electrons, with certain energies and small momenta, could be ejected from the material and detected.

The Central Laser Facility's Artemis beamline at the Rutherford Appleton Laboratory is one of the first in the world to overcome this limitation. It uses extreme ultraviolet (XUV) pulses from high-order laser harmonics, with 20 eV photon energy and 30 fs time resolution. XUV high harmonic pulses are created when a short pulse laser is focused into a gas-jet and interacts with the gas, producing even shorter pulses of coherent radiation in the 10-100 eV range. The higher photon energy enables electrons with a much wider range of energies and momenta to be detected, meaning that each snapshot of electronic structure has a much wider field of view.

This turns out to be particularly important for experiments on graphene. Many of the peculiar properties of graphene are due to an electronic structure called the 'Dirac cone' – an hourglass-shaped region of electrons in momentum space. Electrons from the Dirac cone can only be ejected from graphene and detected if the photon energy is above 16 eV, making an XUV high-harmonic probe pulse essential to observe the extraordinary electron behaviour.

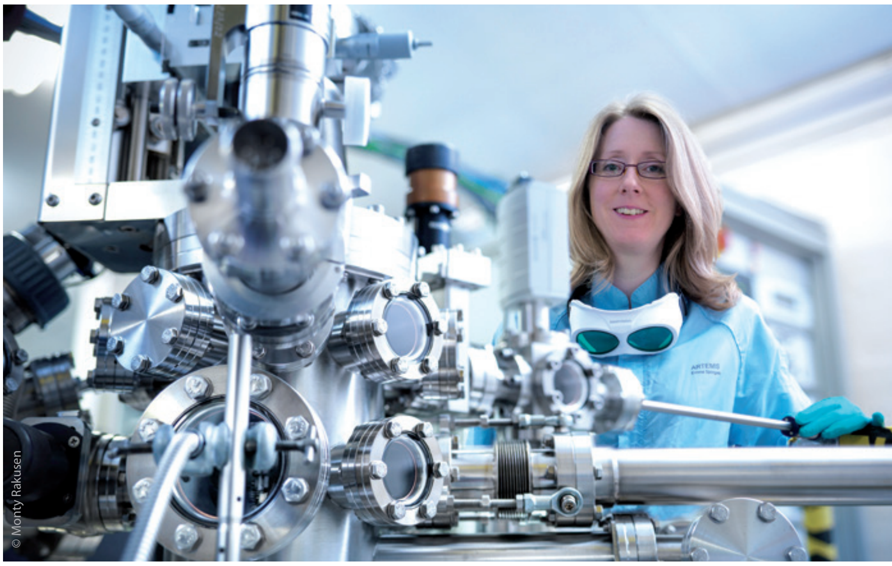
Laserlab-Europe provided funding for access to Artemis. Two proposals to investigate graphene on Artemis were successful at the access round. The two teams made the first direct measurements of electron dynamics in graphene and raced to write up, posting their papers on the archive within days of each other.

Direct view of hot carrier dynamics in graphene

The first experiment addressed the questions of whether graphene could be an efficient solar cell material and how the excited electrons in graphene actually decay. The team was a pan-European collaboration from five countries, led by Philip Hofmann from Aarhus University in Denmark. Two groups from EPFL in Switzerland and Aarhus University specialise in high-resolution ARPES measurements at synchrotrons. A team from three institutes in Trieste (Italy) provided expertise on time-resolved ARPES, TU Chemnitz (Germany) grew and characterised the graphene monolayers and the UK team at Artemis ran the beamlines.

The team were the first to publish their measurement of electron dynamics in graphene. They were able to directly measure the time-, energy- and momentum-resolved distributions of hot electrons in graphene after laser excitation. "The high photon energies available at the Artemis laser facility are opening a completely new perspective for studies of excited electrons", Philip Hofmann explains. "While we have seen many similar experiments on model systems to study the technique, we now have access to a wide range of fascinating materials, not only graphene but also other two-dimensional systems."

The team then looked for evidence of 'carrier multiplication' – multiple electron-hole pairs generated for every photon absorbed. Theoretical predictions have suggested this could be a way of making solar cells more efficient. The team saw that carrier multiplication was not present under these conditions, but that their measurements were consistent with theory predicting that it will happen in graphene in the conditions of weak sunshine actually relevant for solar cells.



Emma Springate (CLF) operating the ARPES end-station at Artemis.

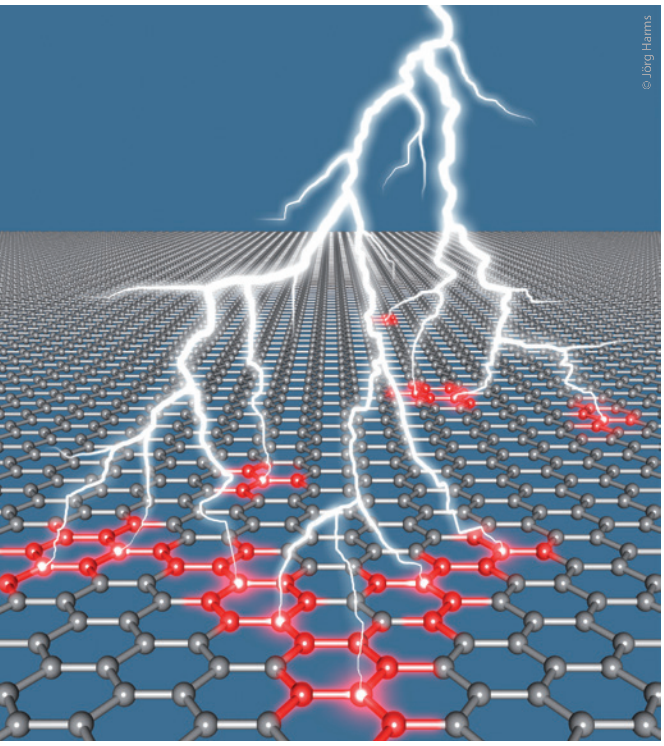
Demonstration of lasing graphene

Theoretical studies and measurements of absorption have previously suggested that graphene could lase in the terahertz (the very long wavelength region of the spectrum, often used for security imaging), but there were no direct measurements.

A Laserlab experiment addressing this challenge was carried out at Artemis by the Max Planck Institute for the Structure and Dynamics of Matter in Hamburg and Oxford University, led by Isabella Gierz. A team from the Max Planck Institute for Solid State Research in Stuttgart were responsible for sample growth and characterisation.

The team used ultra-short flashes of infrared light to excite graphene and unexpectedly found that a population inversion can be produced. The discovery was surprising because graphene lacks a classic semiconductor property long considered a prerequisite for population inversion: a band-gap. The band-gap is a region of forbidden states of energy, which separates the ground state of the electrons from an excited state with higher energy.

Graphene, a honeycomb lattice made of carbon atoms, is a suitable material for lasers emitting ultrashort terahertz pulses.



Because of the absence of a band-gap, the population inversion in graphene only lasts for around 100 femtoseconds. "That is why graphene cannot be used for continuous lasers, but potentially for ultrashort laser pulses", lead scientist Isabella Gierz explains. The measurements indicate that graphene could be used to amplify terahertz light which is currently only produced using inefficient nonlinear processes. A terahertz graphene laser would be particularly useful for research in condensed matter physics.

The Hamburg-based team came to a similar conclusion on the possibility of using graphene for solar cells. "According to our measurements, a single photon in graphene cannot release several electrons", Gierz says. "However, one may speculate that more favourable conditions for carrier multiplication may be met for negligible doping of the graphene layer, smaller pump fluences and higher excitation energies."

Both teams have already been back to Artemis for another round of successful experiments, and are in hot competition.

Emma Springate
(Head of Artemis, Central Laser Facility)

Publications from Laserlab experiments

Snapshots of non-equilibrium Dirac carrier distributions in Graphene, I Gierz, JC Petersen, M Mitrano, C Cacho, ICE Turcu, E Springate, A Stöhr, A Köhler, U Starke, and A Cavalleri, Nature Materials **12** 1119 (2013).

Direct view of hot carrier dynamics in graphene, JC Johannsen, S Ulstrup, F Cilento, A Crepaldi, M Zacchigna, C Cacho, ICE Turcu, E Springate, F Fromm, C Raidel, T Seyller, F Parmigiani, M Grioni, and P Hofmann, Phys Rev Lett **111** 027403 (2013).

HiPER plans for LMJ access

Academic access to beam time at the Laser MegaJoule (LMJ) and PETAL facilities, currently under construction in Bordeaux, has recently been agreed between the CEA, owners of the facilities, and the French Government. This is important for HiPER as access to LMJ opens up the possibility of demonstrating ignition, and ultimately high energy gain, which is essential for the commercial viability of power production from inertial fusion.

An EU-funded COST programme entitled 'Developing the physics & the scientific community for inertial confinement fusion at the time of NIF ignition' has recently been awarded to the University of Bordeaux. Its aim is to support the academic community in preparing bids for experimental campaigns at LMJ.

The kick-off meeting, chaired by Prof. Dimitri Batani, was held from 5th to 7th March 2014 at the University of Bordeaux in Talence. Over two hundred researchers from Europe, Russia, the United States and Japan discussed recent advances in laser-driven plasma science, including inertial confinement fusion, particle acceleration, matter in extreme conditions, and laboratory astrophysics. One of the highlights of the meeting was a visit to the LMJ facility itself.

This meeting helped the community to appreciate the scale of the task to field experiments at fusion scale, the requirements for development of precision diagnostics and the numerical simulations needed to underpin the design and analysis of experiments.

Breaking points for ELI

ELI-ALPS – and, hence, ELI as a whole – has just taken another huge step on its way towards implementation. The European Commission officially released the first and major part of the over 200 million euro EC contribution towards the construction of ELI-ALPS in the first week of May 2014.

ELI-ALPS had already been well on its way, though, and spending money for quite some time, due to a pre-financing arrangement with the Hungarian government. ELI-Beamlines in Prague received its equivalent EC funds already in 2011, and ELI-NP in Magurele in 2012. Construction at the Czech and Romanian sites is making impressive progress, as can be monitored in real time on their respective web sites.

ELI-NP recently celebrated the conclusion of a multi-ten-million euro contract for delivery of a world-wide unique gamma beam source. A contract over delivery of two 10-petawatt lasers had already been concluded earlier, similar to a contract over a 10-Hertz, diode-pumped petawatt laser to be built by Livermore for ELI-Beamlines in Prague.

The Romanian lasers will be built by a French company, while the gamma beam source will be developed by a European consortium of companies and institutions under the leadership of the Italian nuclear physics institute INFN – demonstrating the international character of ELI and its close cooperation with industry and academia during implementation.

The Hungarian Prime Minister Victor Orban (right) and Wolfgang Sandner, General Director of the ELI-DC International Association (left), laying the Foundation Stone for the ELI-ALPS facility in Szeged, Hungary, on February 6, 2014 together with Lorant Lehrner, Managing Director of ELI-ALPS.

The pan-European character of the ELI project has recently been further strengthened by the British Science and Technology Facilities Council STFC with its CEO John Womersley (also ESFRI Chair) having officially joined the ELI-DC International Association. STFC and the Central Laser Facility will jointly represent the UK in the Association.

Forthcoming events

Foresight Workshop 'Lasers for Life'
2 – 4 June 2014, London, UK

5th Target Fabrication Workshop
6 – 11 July 2014, St Andrews, Scotland

LA3NET 3rd School on Laser Applications
29 September – 3 October 2014, Salamanca, Spain

Laserlab User Meeting 2014
29 – 30 September 2014, Prague, Czech Republic

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 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 setup, 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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Issue 18 | December 2014

Laserlab Europe

Laserlab Forum

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

Lasers for Solar Energy

Quantum simulation of a portion of an organic solar cell composed by a polymer chain, and a fullerene buckyball.

In this Issue

Editorial

Tom Jeltes

In my view, the two main themes of this issue of Laserlab Forum perfectly illustrate the broad scope of laser science. On the one hand, probing the details of the charge separation process in solar cells, as described in the Focus and Access Highlight sections, requires utmost delicacy and precision. On the other hand, the contribution on the Laserlab workshop about laser targets represents the more destructive extreme of the laser application spectrum. This becomes especially clear as the target community's focus shifts towards targets for extremely high-power laser facilities as ELI and HiPER.

From microwatts to gigajoules, and from tabletop experiments to industrial-sized facilities, each extreme of laser science requires its own type of experts and organisational structures. One thing they have in common, though, is that both tabletop low-energy and extremely high-energy lasers are currently instrumental in the development of sustainable and clean sources of energy.

Solar energy has already gained a presence in the every-day life of many European citizens (I for one have solar cells on my roof), and this will become even more so if our increased understanding of the basic processes in solar cells (gained at least partly by laser science) will lead to cheaper and more versatile solar technologies. And if developments in the field of Inertial Confinement Fusion Energy will be successful, lasers might just also play a starring role in the mass energy production of the future.

I am not surprised the United Nations proclaimed 2015 the International Year of Light…

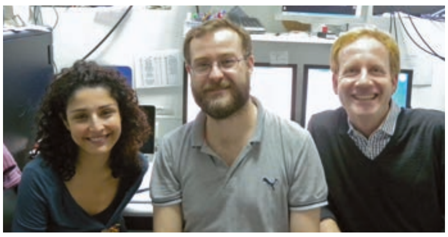
Tom Jeltes

News

Researchers at IESL achieve the brightest atom laser ever

The BEC and Matter Waves group of Laserlab-Europe partner IESL-FORTH (Crete) has demonstrated the brightest atom laser to date. They removed a fundamental limitation in the outcoupling of an atom laser from a Bose-Einstein condensate, which allowed them to demonstrate an atom flux seven times larger than what was previously possible.

An atom laser emits a beam of coherent atoms in much the same way as an optical laser produces a beam of photons. Such a beam of atoms may be used for atom lithography or for precision measurements of, for example, rotation, gravity, and magnetic fields. The atom laser was produced by releasing so-called Bose-condensed atoms, which were magnetically trapped at a temperature of near absolute zero.



Vasiliki Bolpasi, Mark Baker, Wolf von Klitzing

Usually, this outcoupling is done by transferring the atoms to a magnetically untrapped state using a weak radiofrequency field – a process which limits the maximum flux of atoms in the atom laser beam. The IESL researchers instead used a much higher rf field, which effectively creates a hole in the magnetic trap, through which the atoms can escape in much larger quantities than anyone attained ever before. With the same technique, they were able to create a thermal atom beam with a temperature of just 200 nanoKelvin, two orders of magnitude colder than any other reported atom beam.

CLARA: Center of excellence planned in Magurele, Romania

Romanian Laserlab-Europe partner INFLPR, together with the Horia Hulubei National Institute for Physics and Engineering, is planning to create a new European Center of Excellence in LAser and Radiation Applications (CLARA) on the existing Magurele Platform near Romania's capital Bucharest.

The Magurele Platform already hosts the largest concentration of nuclear physicists in Eastern Europe. The brand new CETAL infrastructure at Magurele supports the most powerful laser in Europe, producing 1 petawatt, 25 femtosecond pulses. In addition, Magurele is also the site of the Nuclear Physics branch of the Extreme Light Infrastructure (ELI-NP), with two 10 petawatt lasers under construction, planned to be operational in 2017.

A proposal for funding of CLARA has been submitted to the European Commission as a Teaming action, a Horizon 2020 funding scheme for associating advanced research institutions to other institutions, agencies or regions for the creation or upgrade of existing centers of excellence.

International Year of Light 2015

INTERNATIONAL YEAR OF LIGHT 2015

2015 is proclaimed as the International Year of Light by the United Nations, highlighting to the citizens of the world the importance of light and optical technologies for their lives, for their future, and for the development of society.

The global initiative of scientific societies and unions, educational institutions, technology platforms, non-profit organizations and private sector partners will show how light and light-based technologies, a cross-cutting discipline of science in the 21st century, have revolutionized medicine and communication, and provide solutions to global challenges in energy, education, agriculture and health. Laserlab-Europe is proud to support the International Year of Light as Collaborating Partner.

Let there be light: GoPhoton!

The GoPhoton! project promotes information in society in general about the ubiquitous and pervasive nature of light-based technologies in our lives. The goal is to make photonics a household word, gaining recognition and support for the opportunities and growth potential that photonics represents for society.

The highlight of the project will be the organisation of PhotonicSplashes across Europe travelling from participating city to participating city throughout 2015, the Year of Light. These PhotonicSplashes will feature many different activities for students, teachers, industry and the general public who all will have the opportunity to learn about photonics by visiting research centres during open day events, going to exhibitions, attending talks, participating in workshops, and taking part in all sorts of educational, entertaining and fun events revolving around the concept and application of light.

As a prelude, the 5th Girls' Technology Congress was held in Berlin on 10 October 2014. About 170 girls aged 12 to 17 learned about light and light-based technologies, about career opportunities in photonics companies and attended several workshops with hands-on experiments. A literary contest "LichtBlicke" was launched inviting girls and boys from secondary schools in the Berlin region to write texts about "light". The best poems or short stories will be translated into music. A final concert will be held at the next girls' technology congress in October 2015.

GoPhoton! is an EC-funded project by the European Centres for Outreach in Photonics (ECOP), involving Laserlab-Europe partners ICFO (Barcelona), ILC (Bratislava) and POLIMI (Milan).

Official inauguration of ASUR laser facility Marseille

On 11 July 2014, more than 100 people were present in Marseille at Laserlab-Europe partner LP3 (Lasers Plasmas and Photonics Processing Laboratory) to attend the official inauguration of ASUR (Applications Sources laser Ultra-Rapides), a new and unique ultrafast, multi-beam, multi-terawatt and high average power laser facility.

The ASUR laser source has been developed by Amplitude Technologies (Evry, France). It is based on state-of-the-art Ti:Sa and CPA technology with four main output laser beams at 800 nm, three of them (for instance low and high energy) being available at the same time. The first beam has an ultra-short pulse duration of ~ 10 fs, with energy and repetition rate values of respectively 100 µJ and 100 Hz while the other three have a similar pulse duration of 25 fs, but different intensities and repetition rate. Up to now, such a source delivering 10 TW at 100 Hz is unique in the world.

Representatives of Aix-Marseille University, CNRS, the European Commission, the French Government, Région PACA, Conseil Général des Bouches du Rhône, and the city of Marseille at the official inauguration of ASUR.

The LP3 laboratory, a joint research institute between Aix-Marseille University and CNRS (Centre National de la Recherche Scientifique) is undertaking numerous scientific projects in collaboration with both industrial and academic partners with the new ASUR facility. Projects include investigation of fundamentals of laser-material interactions, ultrafast laser damaging of optical components, and high repetition X-ray production, as well as pump/probe experiments and application to nanoscience and biophotonics.

ICFO awarded funding for study of neurodegenerative diseases

The SLN Lab at Laserlab-Europe partner ICFO – The Institute of Photonic Sciences, led by Dr. Pablo Loza-Avarez, has recently been awarded with funding for two different projects under the 'la Marato de TV3' call, an annual telethon broadcast by Catalan TV to raise funds for scientific research into diseases which are currently incurable. The optical facilities of the SLN Lab will be used to study molecular processes in the retina of multiple sclerosis patients and people suffering from retinal dystrophies.

Multiple sclerosis (MS) is an inflammatory and neurodegenerative disease, which also inflicts significant damage to the retina. Studying the molecular changes caused by MS within the retina (which is much more accessible than, e.g., brain tissue) might give insight in how the disease progresses and how exactly nervous cells are damaged.

In the first project, Raman spectroscopy, a laser technique by which molecular species can be identified on account of their vibrational frequencies, will be used to find molecular signatures associated with the different kinds of MS. The hope is that better understanding of the disease can be obtained using Raman spectroscopy on the retina.

The second project addresses different neurodegenerative disorders: inherited retinal dystrophies leading to blindness by alteration of the rods and cones (the light-sensitive cells) in the retina. The state-of-the-art microscopy facilities of the SLN Lab will be used to study the transport of specific proteins in these photoreceptor cells in mouse models which carry two different retinal dystrophy genes, in order to gain better understanding of how these genes are responsible for the observed symptoms.

Lasers for Solar Energy

Only a small fraction of the incident solar radiation is needed to cover the global energy demand. As such, solar energy has a huge potential as a sustainable source of energy. Indeed, the percentage of electricity generated from sunlight has grown quickly over the past few years, mainly because of the highly successful crystalline silicon solar cells. In order to sustain this growth, though, the world needs new solar technologies, which can provide cheaper and – quite literally – more flexible solar materials.

Various kinds of thin-film and organic ('plastic') solar technologies are currently under investigation. They offer huge potential for low-cost solar energy production, as they can be produced on a large scale from solution by so-called roll-to-roll processing, much like newspapers are printed. In addition, these alternative technologies offer nearly endless possibilities to tune the optical absorption by changing dyes, dopants, or the structure of the organic molecules used.

In order to find out which combination of materials – and in which configuration – gives the best results, detailed understanding of the physical and chemical processes inside the solar material is of crucial importance. And since those processes take place at ultrashort timescales (billionths of a billionth of a second) and the lengthscale of atoms, exceedingly fast and accurate measurements are required.

Fortunately, modern laser science provides the tools needed to follow the fundamental processes of solar electricity generation: the liberation of electrons (and their positively charged counterparts, called 'holes') from the active material by impinging photons, and their subsequent separation towards the electrodes.

This focus section features stories from several scientists within Laserlab-Europe, partners as well as users, giving a flavour of the solar technologies under study and the laser techniques that are used to look into their workings.

Perovskite solar cell materials probed by ultrafast terahertz spectroscopy

The past few years have witnessed the rise of a spectacularly promising new photovoltaic material: organometal halide perovskite. Researchers at Lund Laser Centre (LLC, Sweden) explored how charge carriers (electrons and holes) move inside this novel material once they are liberated by sunlight.

In the short span of three years, the overall power conversion efficiency (PCE) of organometal halide perovskite (OMHP) solar cells have shot up from 7.3 % to 19.3 %. This sharp rise of the power conversion efficiency is unprecedented and unmatched by any other solar cell technology since the conception of harvesting sunlight. As a result, the solar cell community is in great excitement and many of its researchers have shifted to the study of this material.

Unlike silicon solar cells, which require highly industrialised settings for fabrication, this material can be prepared in the laboratory (kitchen chemistry) where a three dimensional mesoscopic scale structure can be achieved.

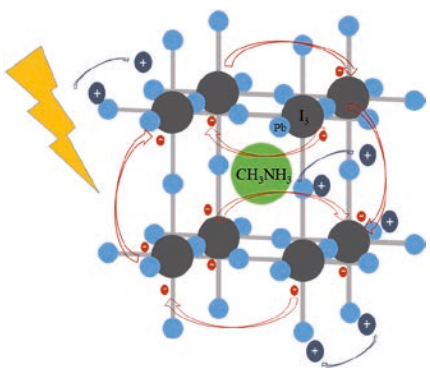
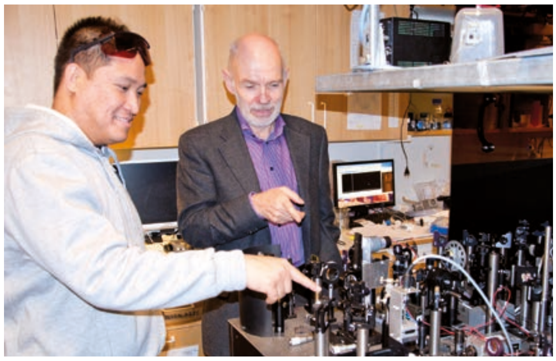


Figure 1: Organometal halide perovskite structure showing the three main constituents – a lead (Pb) ion, iodide (I_3) and methylamonium (CH_3NH_3) ions. The red and blue arrows illustrate the efficient micrometre scale diffusion of photogenerated electrons and holes.



Carlito S. Ponseca Jr. and Villy Sundström in a laboratory at Lund Laser Centre

Several different configurations of the OMPH have been explored for solar cells – as sensitiser of nanostructured metal oxides (e.g., TiO_2), porous thin films, vapour deposited thin solid films, etc.

Scientists at the Lund Laser Centre, in collaboration with researchers in Delft and Geneva, have explored the charge carrier dynamics in these new materials employing a combination of ultrafast THz and optical spectroscopy. Some of its nearly ideal solar cell characteristics reported include ultrafast generation of excitons (around 100 femtoseconds), which then separate into highly mobile charges in 2-3 picoseconds.

Electron and hole mobilities in neat OMPH were estimated to be 12.5 cm^2/Vs and 7.5 cm^2/Vs, respectively, at least two orders of magnitude higher than in organic solar cells, and remain mobile up to the microsecond timescale, beating organic solar cells by at least three orders. Not only the exciton binding energy is small (around 35 meV), thereby allowing fast dissociation of bound electron-hole pairs, but it also requires 90 meV of activation energy for these charges to recombine. This leads to very slow charge recombination and micrometre scale electron and hole diffusion lengths, again winning over organic solar cells by at least three orders of magnitude.

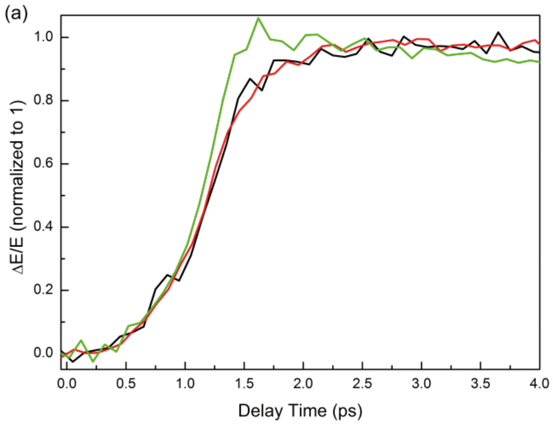


Figure 2: THz conductivity shows that highly mobile charges appear in a few picoseconds in various OMHP materials following femtosecond pulse excitation. Black – neat OMHP; red – nanostructured OMPH/Al_2O_3; green – nanostructured OMHP/TiO_2. Taken from Carlito S. Ponseca Jr. et al., J. Am. Chem. Soc. 136, 5189 (2014)

When used as sensitiser to a nanostructured TiO_2 electrode, ultrafast, < 1 ps, electron injection from perovskite to TiO_2 is observed (figure 2), leading to long lived charge carriers that can be efficiently extracted as photocurrent. Several avenues are currently being explored in order to push overall power conversion efficiency further. This includes looking for higher conductivity hole transporting materials, optimizing growth processes for more uniform morphology of the perovskite, and using perovskite-based cells in tandem with silicon solar cells.

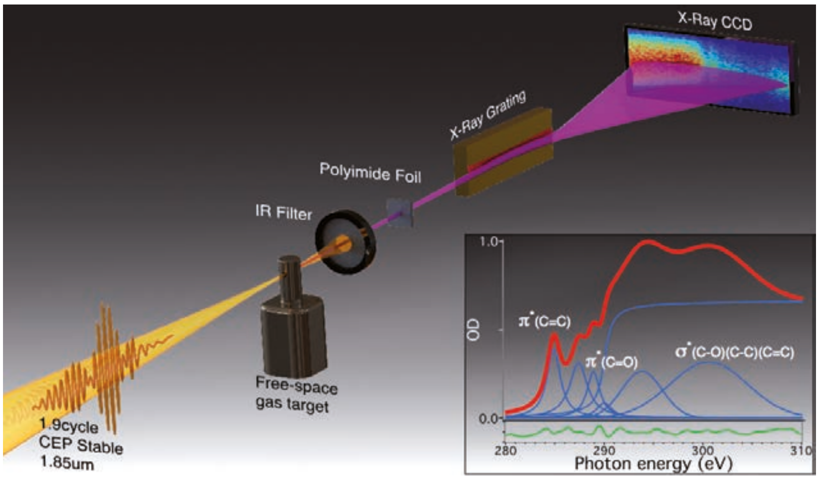
Carlito S. Ponseca Jr. and Villy Sundström
LLC

Tabletop soft X-ray device for probing molecular fine structure in solar materials

At ICFO, Barcelona, the first tabletop ultrafast X-ray absorption measurements were recently demonstrated using a high harmonic generation (HHG) laser source in the water window. This source is now available through the Laserlab access programme and is particularly suited for looking at excitations and structure of organic solar cell materials.

Control and catalysis of a chemical reaction, or efficient conversion of a photon from sunlight into an electronic current within a solar cell, require precise coordination of the numerous steps across energetic barriers and along complicated reaction pathways. In order to understand and steer these processes, we need new quantitative experimental tools that can track time-evolving structural changes and electronic excitations in a comprehensive manner, i.e., we have to get access to the initiation reactions without missing any of the fastest dynamics (taking place at attosecond timescales) or smallest structural changes (at the Ångstrom level).

The wavelength range from 2.3 to 4.5 nm, called the 'water window' because water is nearly transparent in this range, is of great interest to scientists since the so-called K-absorption edges of the building blocks of life, carbon, nitrogen and oxygen all fall within this wavelength range. These so-called soft X-rays can thus be incredibly useful for element-specific high resolution imaging and spectroscopy. Facility scale light sources, namely synchrotrons and X-ray free electron lasers, have so far been the only sources of these extreme short wavelengths. High harmonic generation (HHG), however, can be an alternative compact and economic source of short wavelength radiation on attosecond time scales.



Sub-2-cycle pulses are focused into a high pressure gas target, generating water window high harmonics. Absorption spectra from a polyimide film are recorded using an X-ray spectrograph. Taken from: S. L. Cousin et al., Optics Letters 39, 5383 (2014).

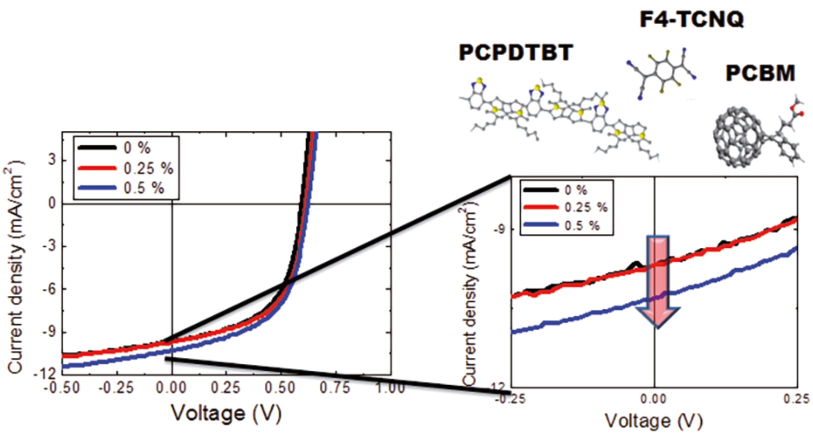
We have recently demonstrated a high flux source of water window radiation and used it to perform high resolution X-ray absorption spectroscopy on a polyimide foil, in which we identify specific absorption features corresponding to the binding orbitals of the carbon atoms. Absorption spectra are recorded in single five-minute integrations, highlighting the high number of X-ray photons generated. The measurements indicate that our tabletop X-ray source is particularly suited for unraveling the processes leading to the generation of electricity in organic (i.e., carbon-based) solar cells.

Jens Biegert
ICFO

Molecular doping of organic semiconductors for photovoltaics

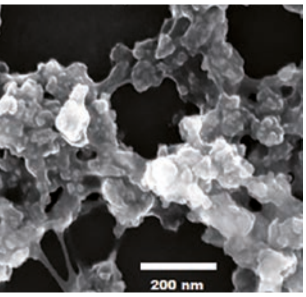
The power conversion efficiencies of organic solar cells have been increasing rapidly due to the design of new organic absorber materials, but the performance of bulk heterojunction solar cells is still inherently limited by the electronically disordered active layer. At LaserLaB Amsterdam, the effect of introducing molecular electron donors and acceptors into the semiconductor material – a process called 'doping' – is studied in detail.

The most widely investigated type of organic solar cell is the polymer:fullerene bulk heterojunction. Soluble poly-



Current-voltage characteristics of PCPDTBT:PCBM solar cells which were doped with low concentrations of the electron acceptor F4-TCNQ to improve the photocurrent and efficiency.

mer and fullerene derivatives are processed from a single solution onto a substrate. Phase segregation between the molecular phases ensures an extended interface for efficient charge separation as well as closed percolation paths for the transport of charge to the electrodes. One of the biggest challenges to improve solar cell efficiency is to correlate the structure of the complex active layer with the opto-electronic response of the device.



Scanning electron microscopy (SEM) image of a thin film of the material MEH - PPV, doped with silica nanoparticles to induce morphological changes which increase hole mobility in organic field effect transistors.

Doping, i.e., introducing electron donors and acceptors into semiconductors, is a strategy which has been widely investigated to improve the electrical properties of inorganic semiconductors. Molecular dopants are strong electron acceptors which will induce electron transfer when introduced into an organic layer, resulting in p-type doping of the organic semiconductor.

This concept has been receiving increasing attention for application in organic electronics. Together with project partners we demonstrated that molecular dopants can be applied to the active layer of polymer:fullerene solar cells based on the low band gap material PCPDTBT. This material has good optical absorption properties for organic photovoltaics, but low carrier mobility values due to the intrinsic electronic disorder of thin PCPDTBT films.

We demonstrated that doping PCPDTBT films with the electron acceptor F4-TCNQ at low concentrations (much less than 1 weight % compared to the polymer) leads to an increase in hole mobility, which was attributed to filling electronic traps in the polymer film by dopant induced charge. In the case of PCPDTBT:fullerene blends, molecular doping with F4-TCNQ was observed to reduce carrier recombination phenomena at the polymer:fullerene interface, leading to efficient charge separation. Proof-of-concept solar cells fabricated from doped PCPDTBT:fullerene blends demonstrated increased photocurrents, leading to increased power conversion efficiencies.

We are a new group at LaserLab Amsterdam, and as a next step we plan to combine our expertise in electrical characterisation, i.e., impedance spectroscopy, with optical techniques such as transient absorption and Raman spectroscopy in order to correlate the energetics and dynamics of excited states in the organic layer with molecular properties, such as structure and morphology.

Elizabeth von Hauff
LaserLaB Amsterdam

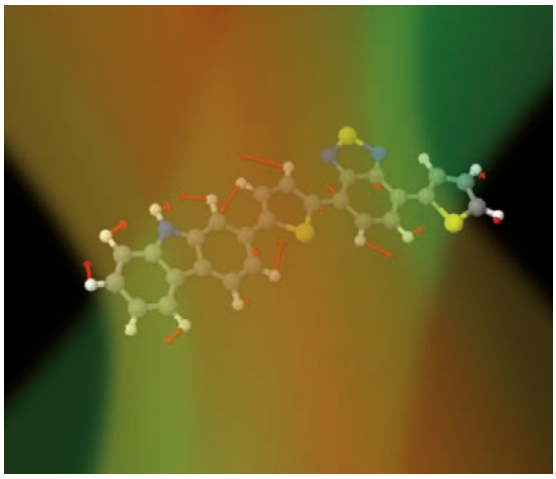
Raman spectroscopy reveals chemical reactions in plastic solar cells

In a recent access project, an international team of collaborators used the femtosecond lasers available on the Central Laser Facility's ULTRA facility to look at the fundamental beginnings of chemical reactions in a new brand of photovoltaic diodes (organic or plastic solar cells), based on blends of polymeric semiconductors and fullerene derivatives.

The access project, which was published in *Nature Communications* in July 2014 (5, 4288), involved teams from the University of Cyprus, the University of Montreal (Canada), Imperial College, and the CLF. It used the ultrafast method of 'Femtosecond Stimulated Raman Spectroscopy' (FSRS), in which laser beams of three different colours are sent onto the solar material, and the subsequently emitted light is collected, revealing details of the internal molecular structure and the processes that took place after the absorption of the laser light.

In 'plastic' solar cells, the absorption of light fuels the formation of a free electron and a positive charged species, called a 'hole'. To ultimately provide electricity, these two species must separate, allowing the electron to move towards the electrode. If the electron is not able to move away fast enough then the positive and negative charges simply recombine and the energy is lost to us. The efficiency of the solar cell thus depends on the fraction of electrons of an electron-hole pair that makes it to the edge of the active material.

Our study provides two key insights into the mechanism of the charge transfer process governing the efficiencies of solar energy devices. Firstly, the work establishes that in the initially created ion pair – generated from the



Femtosecond Stimulated Raman Spectroscopy (FSRS) requires three laser beams to record the structural changes occurring when the material is excited. First, a green pulse activates the polymer to create an electronic excited state. Then, a pair of near infra-red and white light continuum pulses are used to generate the Raman spectrum that records vibrational modes of the excited molecule. The ultrashort lasers pulses enable a time resolution of less than 300 femtoseconds. Credit: University of Montreal.

excited state created by photon absorption – the electron moves away from the positive centre, leading to a prompt molecular rearrangement, with the molecular system resembling the final products within around 300 femtoseconds.

Secondly, we noted that any ongoing relaxation and molecular reorganisation processes following this initial charge separation, as visualised using the FSRS method, should be extremely small. These findings open avenues for future research into understanding the differences between material systems that actually produce efficient solar cells and systems that should be as efficient but in fact do not perform as well, perhaps because a molecule's structural rearrangement is too slow to stabilise and maintain charge separation. A greater understanding of what works and what doesn't will obviously enable better solar panels to be designed in the future.

Tony Parker
CLF

Artificial photosynthesis: creating solar fuels

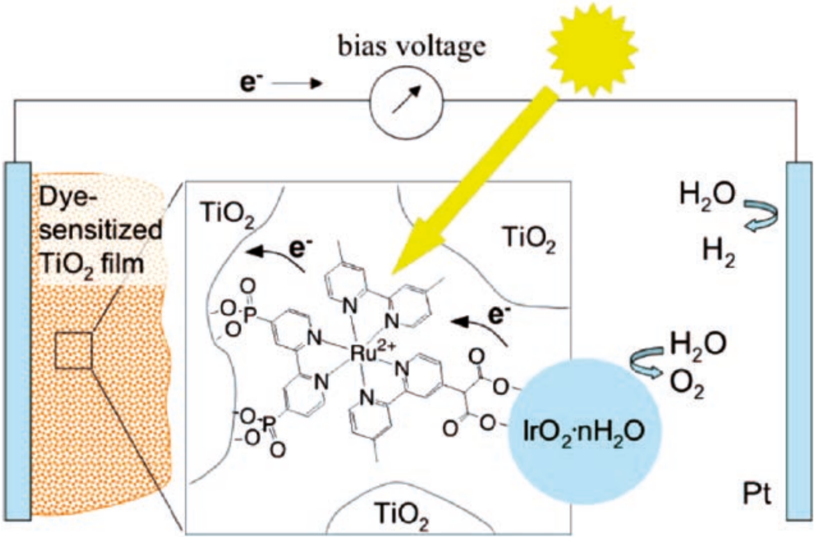
In addition to using sunlight to produce electricity or heat, solar energy can also be used to create fuels. At LaserLaB Amsterdam, efforts are undertaken to understand the basic steps of a process which takes its inspiration from nature: artificial photosynthesis.

Over the past decades, the use of solar energy has been on the rise but has been limited to electric conversion through photovoltaic cells and photothermal methods (using solar heat). However, the sun doesn't always shine and it is very difficult to store electrical energy. For this reason, our society is to a major extent built around the use of fuels rather than electricity.

Artificial photosynthesis, also termed solar fuel production, can remedy this situation: here the energy from sunlight is directly converted to a fuel which can be easily stored. We take our inspiration from natural photosynthesis, where electrons and protons are taken from water and used to generate high-energy organic compounds. We can mimic the basic steps using molecular assemblies similar to those found in photosynthesis, use solid state semiconductors with the right properties or even biohybrid devices.

However, large knowledge gaps exist today on how to efficiently store solar energy in fuels: present-day artificial photosynthesis devices do not perform greatly and are generally not very stable in sunlight. We do not understand these poor qualities at all because we have no idea what happens with the energy and charges once a solar photon has been absorbed. Charge recombination processes arising from bare thermodynamics compete with every forward step, meaning that completion of a successful water-splitting and fuel-production cycle literally is a race against time!

Here, advanced laser spectroscopy enters the game. Using lasers we can determine and control pathways and



Schematic of an artificial photosynthetic system

mechanisms of energy and charge transfer processes, and identify the loss processes that get in the way of the performance of solar fuel devices. At LaserLaB Amsterdam, we run a research programme to address these issues through the application of advanced time-resolved spectroscopic methods.

Unique features of the experimental approach include access to the entire time span between photon absorption and catalytic turnover, i.e., from femtoseconds to milliseconds, infrared and Raman detection methods that provide molecular specificity and information on local structure, and multi-pulse capability to manipulate the dynamics of catalytic intermediates with preservation of time resolution.

Detailed knowledge about the pathways and (loss) mechanisms of energy and charge transfer will help in a design steering feedback loop with organic chemistry, supramolecular catalysis, and solid-state surface catalysis groups to optimise the performance of artificial photosynthetic modules.

John Kennis
LaserLaB Amsterdam

Charge transfer processes in dye-sensitised solar cells revealed

Dye-sensitised solar cells (DSC), thin film cells which can be built from cheap materials and could be cost-effectively processed by roll-to-roll manufacturing, have been the focus of intensive studies since the invention of the concept a quarter of a century ago. Finnish Laserlab-Europe User Representative Jouko Korppi-Tommola and his team have been studying these solar cells for almost two decades, making use of several Laserlab-Europe access facilities to unravel their inner workings.

For a long time, the efficiency of dye-sensitised solar cells, mostly using ruthenium-based dyes, improved only marginally, remaining around the magic 10%. Unexpectedly, a new light absorbing perovskite material was intro-

Dr. Liisa Antila with a dye sensitised solar cell.

duced in 2012. The concept developed rapidly and new records have appeared in quick succession, leading to a veritable perovskite solar cell boom. However, there is no fundamental understanding of charge transfer processes in perovskite solar cells yet, and the development of perovskite-based cells may greatly benefit from previous work on DSCs, where we have been active for a long time.

Our research group at the Nanoscience Center of the University of Jyväskylä entered the study of fundamental charge transfer processes of DSCs after being able to get one of the first 1kHz amplified Ti:sapphire lasers in Europe in the lab in 1996. Soon we realised that there are two charge transfer regimes for the electrons to go from the sensitiser dye to the titanium oxide semiconductor, one faster than 100 femtoseconds and the slower one lasting from a few picoseconds to about 100 picoseconds.

Since our time resolution at that time was not good enough to resolve the sub 100 femtosecond injection, contact was sought with Lund Laser Centre (Villy Sundström). Access days were granted and the first Laserlab-Europe visit realised. Two smart students, Gabor Benkö (Lund) and Jani Kallioinen (Jyväskylä), had the Lund laser working for two weeks at sub 30 femtosecond time resolution, which allowed resolving the fast injection rate and consequently writing the full story for electron injection dynamics in the ruthenium dye based DSCs in 2002. The papers have become the landmark in the field.

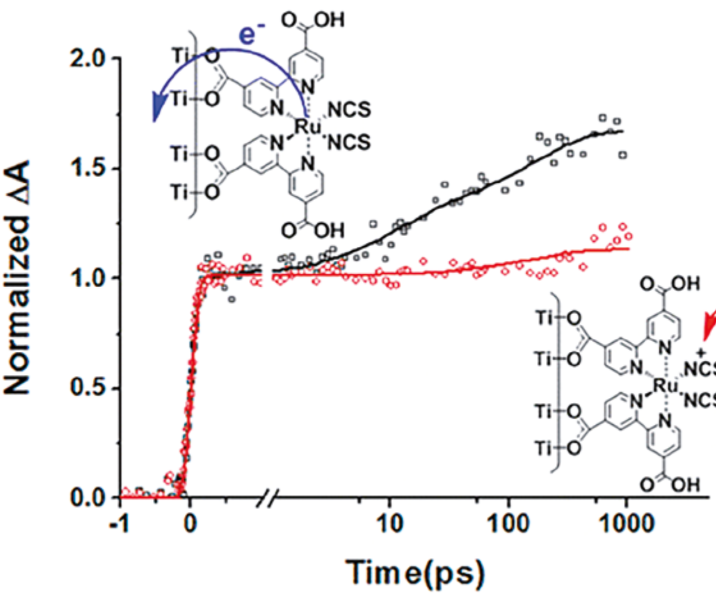
Work continued in search of new ruthenium dyes that were delivered by the chemists from the University of Eastern Finland. These dyes span two more Laserlab-Europe access visits: one to MBI (Berlin) with Erik Nibbering and one to CUSBO (Milan) with Giulio Cerullo. The mid-infrared instrumentation available at MBI was used to unravel vibronic details of the photoreactions of the dyes, revealed the potential of mid-infrared technology. Better time resolution than available either in Jyväskylä or at MBI was still needed and this was found at CUSBO, where newly developed 30 femtosecond UV pulses were used for excitation, and their 7 femtosecond pulses for probing. Again a complete picture was obtained.

Work on DSCs in Jyväskylä continued with use of atomic layer deposition (ALD) in hope to generate subnanometre barrier layers on the photo-electrode that would slow down recombination reactions of the cell. Aluminum, hafnium and tantalum oxide layers were studied. In 2010, mid-infrared instrumentation became operational for 1DIR and 2DIR measurements in Jyväskylä. By combining the results from probing the dye cation formation on the photo-electrode by using near-infrared pulses, and accumulation of electrons in the titanium oxide conduction band by using the mid-infrared pulses, we were able to unravel the first charge regeneration steps of the DSCs, 22 years after the invention of the cell.

This is a good example of how science proceeds in steps with unpredictable timespan between the steps of advancement. To get understanding of fundamental phenomena underlying a seemingly simple function, in this case current production of the cell, one has to have good partners and excellent equipment to solve the problem. This is where Laserlab-Europe access has helped us a lot.

The visit to CUSBO in 2004 determined my fate to become involved in Laserlab user activities. Sandro De Silvestri asked me if I would be interested. Now, ten years later, I hope that I have been able to convey my experiences as a user to the user community of Laserlab-Europe, and I hope to be able to continue doing so.

Jouko Korppi-Tommola
University of Jyväskylä



Charge recombination in N719 sensitised DSC after excitation at 530 nm and probing with 820 nm pulses. Black curve: Formation of dye cation on the photo-electrode in contact with neat solvent 3-methoxypropionitirle. Red curve: Disappearance of the cation signal when photo-electrode is in contact with the full electrolyte revealing the first regeneration step, the iodide attack to the dye after electron delivery. Details see JPCC 118, 7772 (2014).

Target Workshops

Europe is witnessing the construction of a number of high repetition rate, ultra-high intensity laser facilities, including Astra-Gemini in the UK, the HiBEF European XFEL beamline in Hamburg, and the ELI facilities. The issues that arise in operating facilities with such extreme environments are becoming increasingly more challenging.
Recently, two workshops sponsored by Laserlab-Europe were held that addressed these issues from the point of view of target fabrication, positioning, and characterisation. On the Laserlab-Europe website, a report can be found on the fifth edition in a series of target fabrication workshops, held in St. Andrews, Scotland, in July. In the text below, CLF's Nicola Booth describes a workshop organised in Abingdon, England, under the umbrella of Laserlab-Europe's NAUUL network, which addressed similar topics – all related to present and future laser targets.

Workshop on Target Interaction Challenges and Developments

It was with the construction of the new European ultra-high intensity laser facilities in mind that a two-day workshop was held in Abingdon, UK, on 28-29 April 2014, on Target Interaction Challenges and Developments. The workshop was attended by 25 participants from 12 institutions across Europe.

The aim of the workshop was to gather together high-intensity interaction scientists and target fabricators to discuss the current and future issues in moving towards high repetition rate operations at ultra-high intensities, which is key to unlocking the potential of current and future laser facilities. The workshop was attended by delegates from established facilities and those that are currently developing their own facilities. The sessions were divided into common themes, in order to allow the discussions at the end of each session to flow freely.

The first session was dedicated to target positioning at high repetition rate. This session was split between current methods of high rep-rate target positioning, for high intensity systems, and future methods for the ultra-intense facilities. As large facilities begin to operate at higher intensities with more complex targetry, the issue of getting targets in the correct position at 10 Hz or higher is increasingly more pressing, and discussions in this session focussed around this issue.

Two sessions were dedicated to high repetition rate targetry, and a further session dedicated to the characterisation of these targets. Target fabrication experts presented their work in the mass production of targets for current and future facilities. Methods of producing novel targets, such as foams and cryogenic targets were discussed, as well as targetry for specific applications, including ion acceleration and high harmonic generation. Issues such as meeting the required specifications of target shape, surface texture and thickness during target fabrication were also discussed.

The third session of the first day was aimed at discussing facility issues that will come with operating at such high repetition rates. The discussions included the damage that occurs to metal coated optics in high intensity facilities and the effects of debris on the laser induced damage threshold of these optics. The sessions of talks were completed on the final morning, with presentations on the issues that are expected from some of the new facilities due to come online in the near future. These included the facilities at Apollon-10P in France, Vega in Spain, the high-energy density science instrument beamline at XFEL, Germany, and the Extreme Light Infrastructure - Nuclear Physics facility, Romania.

The final session of the meeting was a very productive discussion session, aimed at encouraging a dialogue and collaborations between the European facilities on the issues identified during this series of talks and discussions. The event was finished with a tour for the delegates of the high power laser target area facilities of the Central Laser Facility (CLF).

Nicola Booth

Real-time movies of light-to-current conversion in organic solar cells

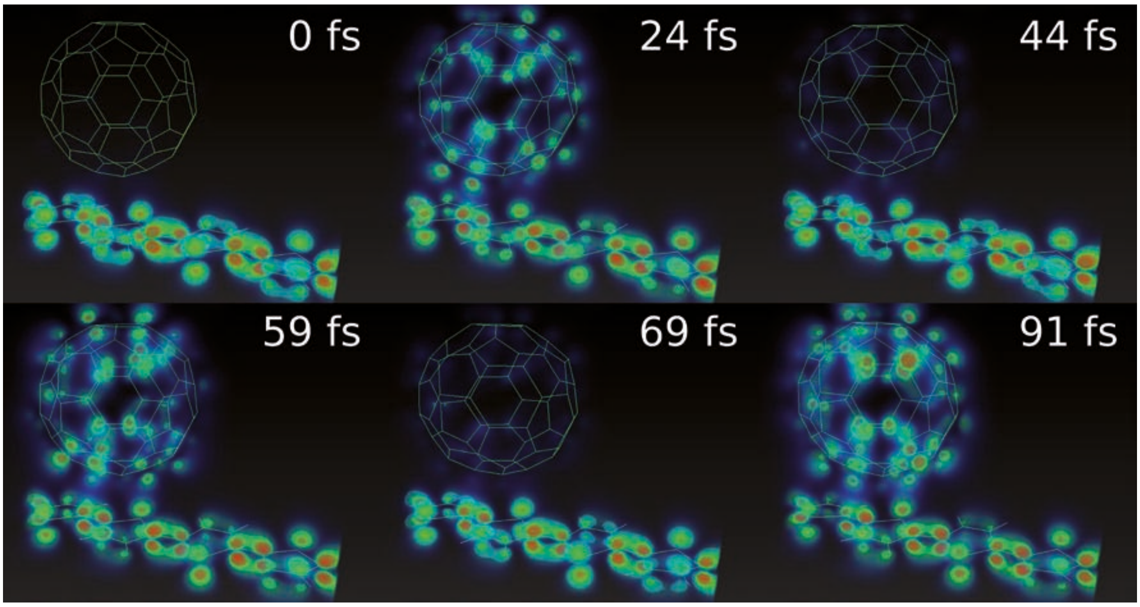
One of the key challenges that mankind has to face in this century is to devise sustainable and clean methods for the production of renewable energy. A recent access project, in which scientists from the University of Oldenburg collaborated with the Ultrafast Spectroscopy group of Giulio Cerullo from Laserlab-Europe partner CUSBO in Milan, has led to an exceptional insight in how light is converted to electrical energy in organic photovoltaic devices ('plastic solar cells'). As demonstrated by 'quantum movies' provided by theorists from the Italian Istituto Nanoscienze, quantum coherence seems to play an important role in the energy conversion process. This new understanding could be used to guide the design of future artificial light-harvesting systems.

Sunlight is a very abundant source of clean energy, but it is intrinsically diffuse. Natural photosynthetic systems have, in the course of evolution, developed sophisticated and highly efficient molecular architectures capable of harvesting the solar energy and storing it into chemical bonds, with an efficiency yet unmatched by any artificial device. One of the key challenges for renewable energy research is to learn how to construct artificial molecular devices which, following the blueprint of natural ones, are able to exploit sunlight either for direct electric power generation (photovoltaic approach) or to drive photochemical reactions which produce fuels (photosynthetic approach).

Traditionally, the primary processes occurring in natural photosynthetic systems, both bacteria and higher plants, have been interpreted in terms of the incoherent energy flow between the different molecular species to the reaction center where charge separation takes place. Very recently a paradigm shift has occurred in the understanding of such processes, indicating that quantum coherence, i.e., the wavelike motion of electronic wave packets, plays a key role in natural photosynthesis. It seems as if nature has designed the molecular complexes in such a way as to protect the typically very fragile quantum coherence and to exploit it to optimize the efficiency of photosynthetic light harvesting. This new understanding, which has been obtained thanks to advanced ultrafast optical spectroscopy techniques, challenges the way we think about natural photosynthesis, and gives rise to the obvious question whether such coherent effects are also present in artificial light-harvesting systems, and can be exploited to optimize their performance.

Looking for an answer to this very fundamental question, Prof. Christoph Lienau (University of Oldenburg, Germany) performed a series of experiments, in the framework of a Laserlab-Europe access project, at the CUSBO (Center for Ultrafast Science and Biomedical Optics) facility in Milan. The goal of these studies, performed in cooperation with the Ultrafast Spectroscopy group led by Prof. Giulio Cerullo, was to investigate, with an unprecedented sub-10-fs temporal resolution, the dynamics of the charge separation process in a prototypical organic photovoltaic (OPV) material consisting of a polymer-fullerene blend.

OPV solar cells typically consist of nanostructured blends of conjugated polymers (long chains of carbon atoms), acting as light absorbers, and fullerenes (carbon buckyballs), acting as electron acceptors. With respect to



Frames taken from the quantum simulation of a portion of an organic solar cell composed by a polymer chain, and a fullerene buckyball. The two parts of the system, separated by a small space, act as the poles of a microscopic sun-operated battery. The quantity depicted illustrates the wavelike oscillations of an electron after sunlight is absorbed at time 0. The time scale is in femtoseconds (fs). Each frame depicts a scene about 2 nanometers wide. By Dr. Carlo Andrea Rozzi (CNR - Istituto Nanoscienze Centro S3, Modena).

Tunable few-optical-cycle pulse generation: the ultrafast spectroscopy setup at CUSBO.

their traditional inorganic counterparts, OPV cells have particularly favorable properties. They are low-cost, lightweight and flexible, and their colour can be adapted by varying the material composition.

The primary and most elementary step in the light-to-current conversion process in OPV cells, light-induced transfer of an electron from the polymer to the fullerene, occurs at such a staggering speed that it has previously proven difficult to follow it directly. Exploiting the unique ultrafast spectroscopy facility developed at CUSBO, which uses different ultra-broadband optical parametric amplifiers to achieve sub-10-fs time resolution combined with broad spectral tunability from the visible to the infrared, the researchers from Oldenburg and Milano were able to record "real-time movies" of the light-to-current conversion process in an OPV cell. In a report published in the May 30 issue of Science Magazine, the researchers show that the quantum-mechanical, wavelike nature of electrons and their coupling to the nuclei is of fundamental importance for the charge transfer in an OPV device.

"Our initial results were actually very surprising", says Christoph Lienau. "When using sub-10-fs light pulses to illuminate the polymer layer in an organic cell, we found that the light pulses induced oscillatory, vibrational motion of the polymer molecules. Unexpectedly, however, we saw that also the fullerene molecules all started to vibrate synchronously. We could not understand this without assuming that the electronic wave packets excited by the light pulses would coherently oscillate back and forth between the polymer and the fullerene."

All colleagues with whom the scientists discussed these results were initially skeptical. "In such OPV blends, the interface morphology between polymer and fullerene is very complex and the two moieties are not covalently bound", says Lienau, "therefore one might not expect that vibronic coherence persists even at room temperature. We therefore asked Elisa Molinari and Carlo A. Rozzi, of the Istituto Nanoscienze of CNR and the University of Modena and Reggio Emilia, for help."

A series of sophisticated quantum dynamics simulations, performed by Rozzi and colleagues, provided movies of the evolution of the electronic cloud and of the atomic nuclei in this system, which are responsible of the oscillations found in experiments. These calculations indicated that the coupling between electrons and nuclei is of crucial importance for the charge transfer efficiency. Tailoring this coupling by varying the device morphology and composition hence may be important for optimising device efficiency.

The question remains whether these new results will immediately lead to better solar cells. "Such ultrafast spectroscopic studies, and in particular their comparison with advanced theoretical modelling, provide impressive and most direct insight in the fundamental phenomena that initiate the OPV process. They turn out to be very similar to the strategies developed by nature in photosynthesis, exploiting quantum coherence to optimize the efficiency of light harvesting", says Christoph Lienau. "Our new result, enabled by the unique experimental capabilities available at CUSBO and by the Laserlab-Europe programme, provides evidence for similar phenomena in functional artificial photovoltaic devices: a conceptual advancement which could be used to guide the design of future artificial light-harvesting systems in an attempt to match the yet unrivalled efficiency of natural ones."

Giulio Cerullo

S.M. Falke et al., Coherent ultrafast charge transfer in an organic photovoltaic blend, Science 344, 1001-1005 (2014)

ELI-DC Management Team reinforced

In September 2014, Dr. Catalin Miron joined the Management Board of ELI-DC (the Extreme Light Infrastructure Delivery Consortium). As Scientific and Technical Liaison Officer (STLO), Miron will be in charge of ELI's internal scientific and technical coordination among ELI's three present pillars. He will also be responsible for contact with the related scientific communities, for structuring the user communities around ELI, and for preparing the transition to the ELI-ERIC, including user access and communication policies.

Among Miron's highest priorities are enhancing cooperation with research organisations and specialised research networks such as Laserlab-Europe and liaising with new and potential ELI user communities. In this context, ELI-DC will initiate a series of coordination actions (scientific workshops, working groups, etc.) aiming at contributing towards the establishment of a framework for a common set of standards for beam parameters and diagnostics at the laser user facilities. Similarly, he will consider quality aspects in terms of user access, control systems and scientific data handling.

Miron is an experienced physicist specialised in radiation/matter interaction and in particular in atomic and molecular science using synchrotron radiation, as well as conventional and free-electron lasers. He contributed to the field of ultrafast dynamics of inner-shell excited species ranging from atoms and molecules to clusters and nanoparticles, and recently led experiments on the foundations of quantum physics. Dr. Miron who previously worked at Synchrotron SOLEIL in France, has coordinated user facilities and research networks, and is a member of several international review panels and journal editorial boards.

In addition to Catalin Miron, the ELI-DC staff has recently been reinforced by Chief Administrative Officer Ms. Annelie Lambert, also member of the Management Board, and by Executive Assistant Ms. Eva Alonso Vizcaíno.

Catalin Miron

HiPER progress

LMJ beamtime for academia

A call for 'Expressions of Interest' (EOI) for beamtime at the Laser Mégajoule (LMJ) was launched in September by the Institut Lasers et Plasmas (ILP) on behalf of CEA. Prof. Dimitri Batani has co-ordinated the HiPER community's submission, which is centred on the development of a shock ignition physics platform leading ultimately to a full-scale shock ignition campaign at the end of the decade.

Opening up of LMJ to the scientific community in 2017 is an outstanding opportunity for plasma scientists throughout Europe to take their research into new and exciting regimes as LMJ is progressively commissioned. As well as the call for a programme on the "direct drive approach to inertial confinement fusion (ICF) for energy", the EOI identifies experiments in high energy density physics, laboratory astrophysics and high energy physics.

Progress towards ignition at NIF

A new campaign to demonstrate increased neutron yield has recently commenced at the National Ignition Facility (NIF) in California. Based on a high density carbon (diamond) ablator and a near vacuum Hohlraum configuration, designed to reduce energy and symmetry losses, initial results are encouraging.

Workshop on IFE at SPIE Lasers and Optoelectronics Symposium

HiPER is hosting a one-day workshop on IFE (Inertial Fusion Energy) physics and technologies within the SPIE Symposium, 13 – 16 April 2015 in Prague. The event will include a Participants' Forum to discuss latest progress and developments in the field.

Forthcoming events

OPCPA Training Course
19-21 January 2015, Bordeaux, France

EUROLITE meeting
26-27 January 2015, Berlin, Germany

Access Board Meeting
30 March 2015, Paris, France

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 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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