Issue 18 | December 2014

Laserlab Europe

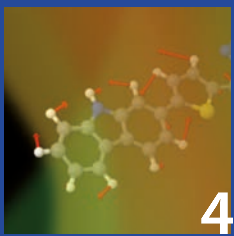
Laserlab Forum

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…

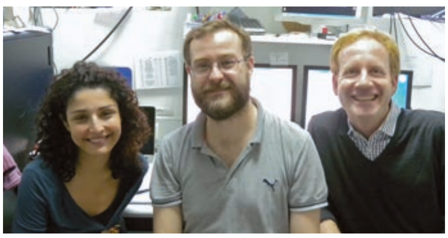
Tom Jeltes

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.

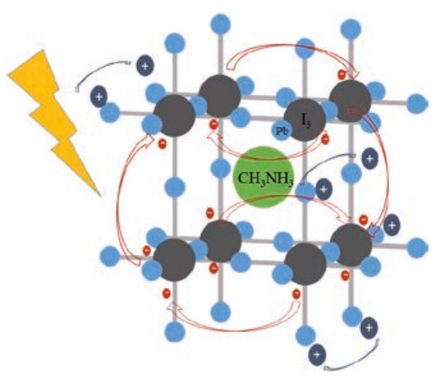
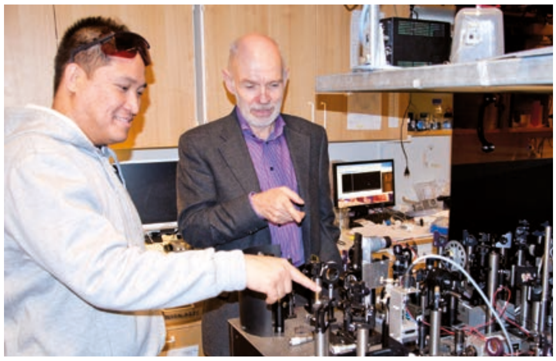


Figure 1: Organometal halide perovskite structure showing the three main constituents – a lead (Pb) ion, iodide (I_3) and methylamonium (CH_3NH_3) ions. The red and blue arrows illustrate the efficient micrometre scale diffusion of photogenerated electrons and holes.



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.

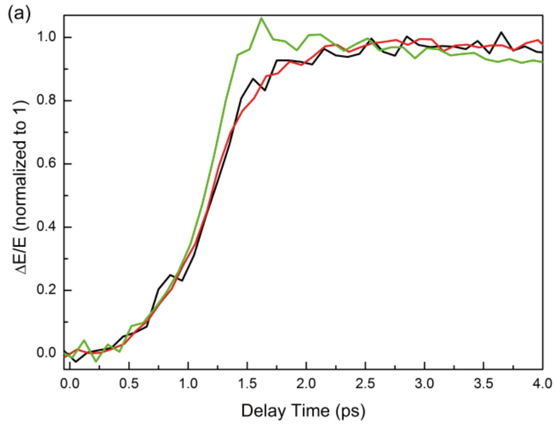


Figure 2: THz conductivity shows that highly mobile charges appear in a few picoseconds in various OMHP materials following femtosecond pulse excitation. Black – neat OMHP; red – nanostructured OMPH/Al_2O_3; green – nanostructured OMHP/TiO_2. Taken from Carlito S. Ponseca Jr. et al., J. Am. Chem. Soc.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

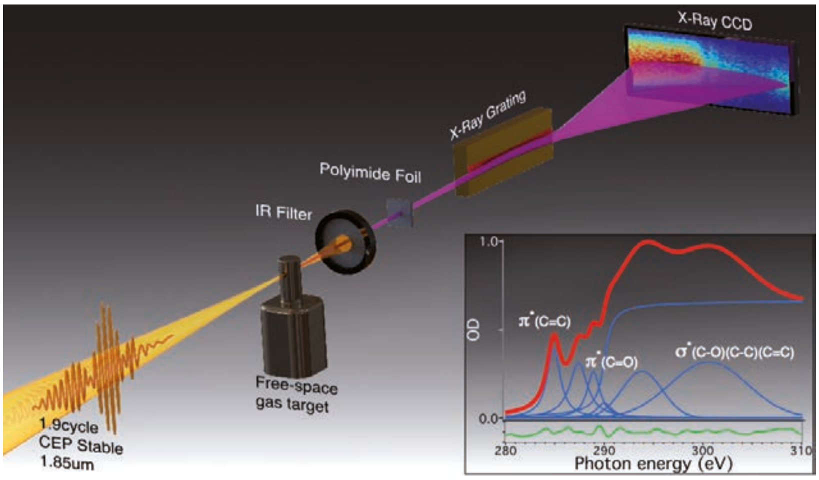
Carlito S. Ponseca Jr. and Villy Sundström
LLC

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).

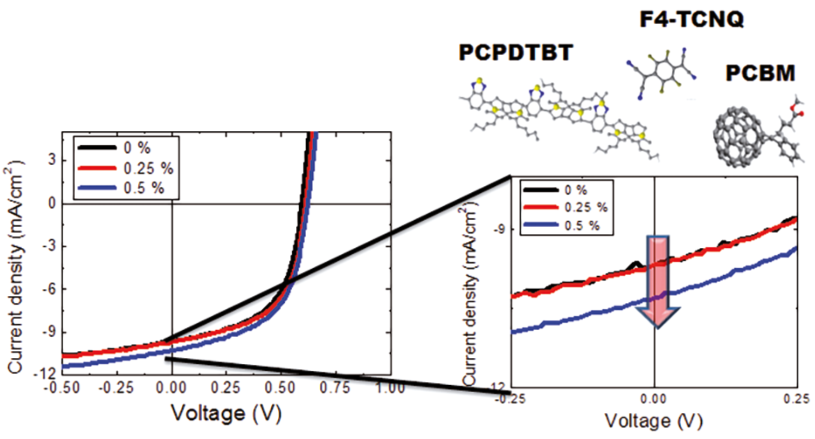
We have recently demonstrated a high flux source of water window radiation and used it to perform high resolution X-ray absorption spectroscopy on a polyimide foil, in which we identify specific absorption features corresponding to the binding orbitals of the carbon atoms. Absorption spectra are recorded 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.

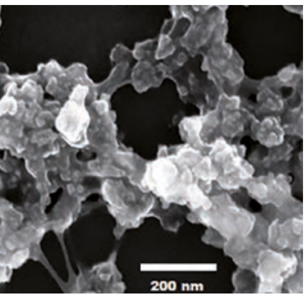
The most widely investigated type of organic solar cell is the polymer:fullerene bulk heterojunction. Soluble poly-



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.

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.



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.

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

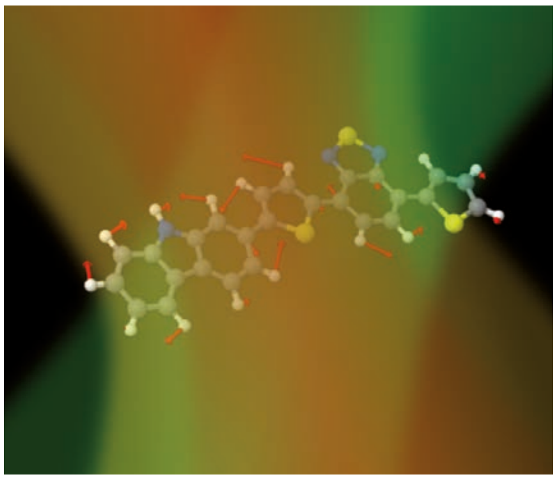
Raman spectroscopy reveals chemical reactions in plastic solar cells

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

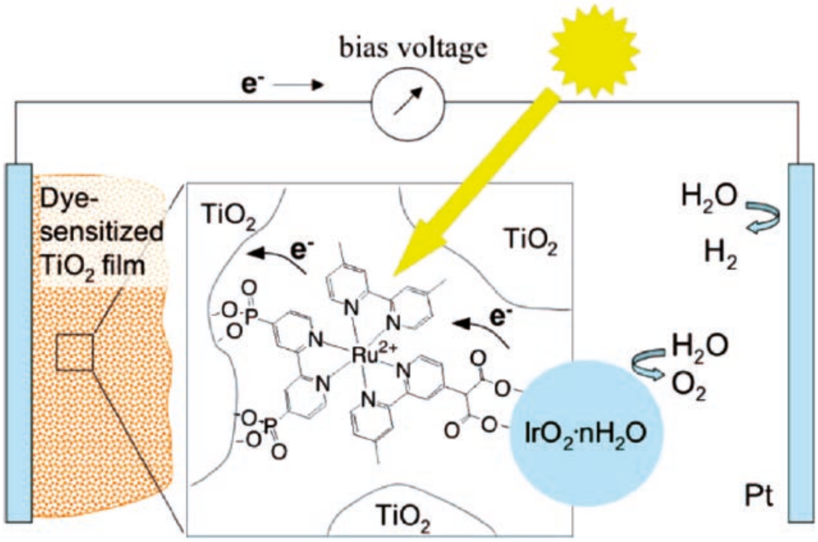
In addition to using sunlight to produce electricity or heat, solar energy can also be used to create fuels. At LaserLaB Amsterdam, efforts are undertaken to understand the basic steps of a process which takes its inspiration from nature: artificial photosynthesis.

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.

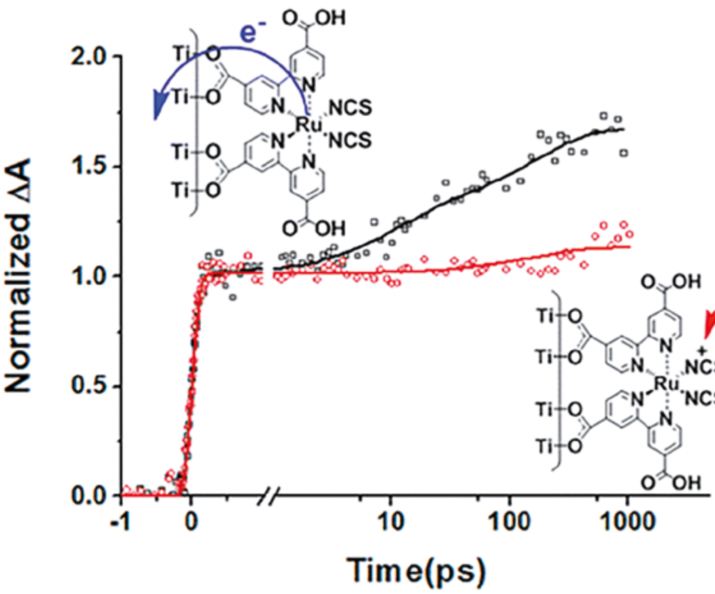
For a long time, the efficiency of dye-sensitised solar cells, mostly using ruthenium-based dyes, improved only marginally, remaining around the magic 10%. Unexpectedly, a new light absorbing perovskite material was intro-

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

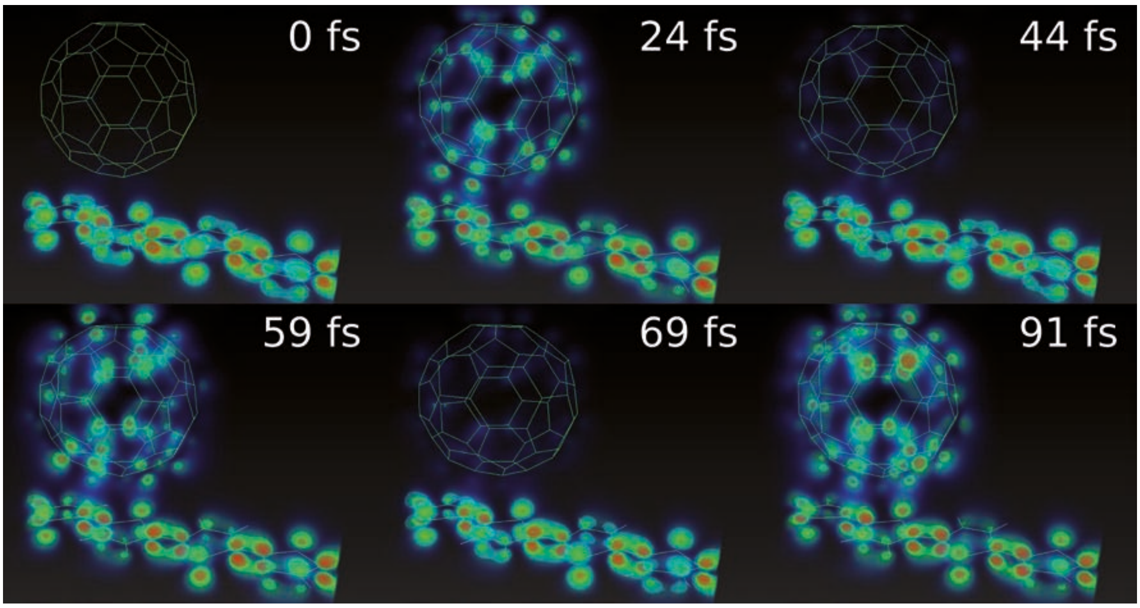
One of the key challenges that mankind has to face in this century is to devise sustainable and clean methods for the production of renewable energy. A recent access project, in which scientists from the University of Oldenburg collaborated with the Ultrafast Spectroscopy group of Giulio Cerullo from 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, light-weight 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.

Laserlab Forum Contact

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

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

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