Laserlab Forum

Laserlab Europe

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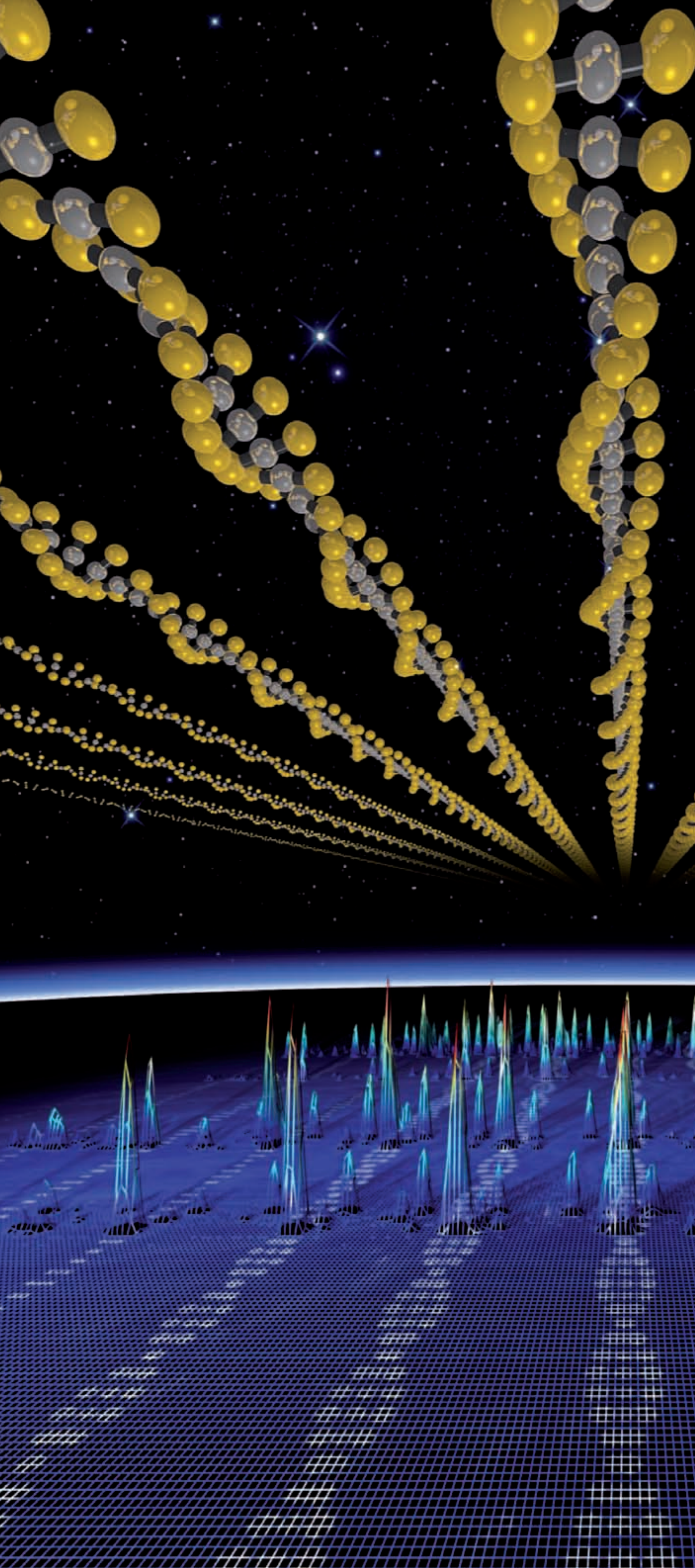


CRASY spectroscopy: The coherent rotation of carbon disulfide molecules (top) is observed in a mass spectrometer and shown as two-dimensional map of correlated mass and rotational spectra (bottom). © MBI

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

News

Editorial

One might distinguish three types of scientists. The first type wants to break records: they try to build the most powerful lasers, with the shortest pulses, highest repetition rate, or shortest wavelength – knowing that every broken technological barrier almost inevitably leads to a scientific breakthrough. The focus of these scientists lies with the instruments needed for the advancement of science. Maybe we should call them Engineering Scientists.

The second type of scientists wants to understand nature on a more fundamental level. They have a more philosophical attitude and are driven by almost existential questions about the nature of dark matter, the origin of mass, or the mechanism behind superconductivity. In general, these 'Fundamental Scientists' need advanced instruments to find the answers to their questions, but their focus is not on the technology required, but on the fundamental questions themselves.

Scientists of the third kind have less difficulty explaining why they do what they do at parties. They want to find renewable sources of energy, cure cancer, restore ancient objects of art, or want to be able to see from the outside whether the contents of a package is dangerous. These 'Applied Scientists' use their scientific training and knowledge to solve the problems that society poses. Of all types of science, this 'Science for Society' naturally has the most direct and visible impact on our everyday lives.

Within LASERLAB-EUROPE, all three types of scientists can be found, as well as every kind of intermediate between the basic types. In this edition of Laserlab Forum, we highlight some research projects that can be classified as 'Science for Society' – a selection of inspiring topics, which will easily convince anybody that (laser) science truly matters. We hope you will enjoy reading.

Tom Jeltes

LENS celebrates 20th anniversary

The European Laboratory for Non-Linear Spectroscopy (LENS), partner of LASERLAB-EUROPE, celebrated its twentieth anniversary on October 18th and 20th 2011 with a busy schedule of events, conferences and seminars at the LENS headquarters in Sesto Fiorentino.

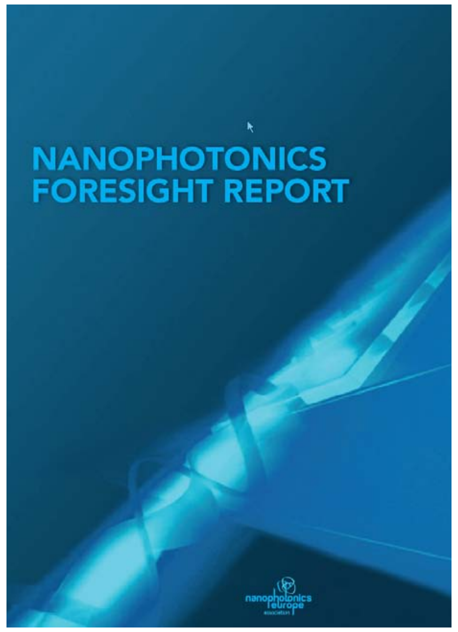
LENS promotes cutting edge research on Atomic Physics, Photonics, Biophysics and Molecular Physics in close contact with the University of Florence and the INO/CNR, but also with the Italian Institute of Technology (IIT) and the Max Planck Institut für Quantenoptik in Germany.

In the two decades since its conception by the University of Florence, LENS has become a leading institute in the field of laser science, says director Diederik Wiersma: "We started in the early 90s by a European-wide initiative of a small group of researchers and we now have 20 laboratories engaged in four main lines of research, more than 100 researchers and students, four projects related to calls of the European Research Council and an average of citations per paper published last year more than 5 times that of Europe".

Among those speaking on the occasion of the twentieth anniversary of LENS were leading names in the international scientific community, including Prof. Theodor Hänsch, Nobel prize for physics in 2005, director of the Max-Planck-Institute für Quantenoptik and professor at the University of Florence and the Ludwig Maximilians University in Munich, and Prof. Albert Polman, director of the FOM-Institute AMOLF in Amsterdam and professor at the University of Utrecht, a pioneer of research in the field of nanophotonics.

Report on future of nanophotonics

In June 2011, ICFO published a report on a Foresight Workshop hosted by the Nanophotonics Europe Association, held in Barcelona in November 2010, where leading scientists in Europe gathered to discuss the future of nanophotonics.



Nanophotonics, where optical nanomaterials can slow down, trap, enhance and manipulate light at the sub-wavelength scale, has become a major research area and is making important advances towards optical communications, (nano)imaging and sensing applications. Researchers are also turning their attention to photovoltaics and light emission to tackle energy issues. However, in translating academic nanophotonics research to industry many practical roadblocks have to be overcome, for example, nanofabrication, manufacturability, cost, etc. With these challenges in mind, the workshop assembled science and technology leaders from across Europe to assess the road ahead for nanophotonics and map the potential industrial impact. The result is a snapshot of the state of the art in nanophotonics as well as research and development topics that are likely to offer important benefits for the photonics industry, society and the research community.

ERC grant for fiber-top technology

Dr. Davide Iannuzzi (LaserLab Amsterdam) received a Proof of Concept Grant from the European Research Council to further develop his ideas for the fabrication of micromachined structures on the tip of an optical fiber.

Iannuzzi invented a series of fabrication steps during his ERC Starting Grant and filed patents for this technology. This new grant of EUR 150.000 will allow Iannuzzi to demonstrate that, thanks to his invention, cost-effective batch production of fiber-top cantilevers is indeed possible. The Italian researcher set up a company, Optics11, to market and sell his products based on fiber-top technology.

The Proof of Concept grant is only open to people who have already won an ERC Advanced Grant or an ERC Starting Grant.

Misha Ivanov appointed as Department Head of MBI

Prof. Mikhael (Misha) Yu. Ivanov has been appointed as Department Head A1 of the MBI and as Professor of Theoretical Optics at the Humboldt University Berlin. At MBI he is the successor of Prof. Martin Weinelt, who accepted a professorship at the Freie Universität Berlin last year.

Misha Ivanov (born 1964) is regarded world-wide as one of the leading theoreticians in the emerging field of ultrafast intense laser science, where novel methods are developed to probe light-matter interactions down to the attosecond time-scale. He has made major contributions to the emergence of attosecond science, and co-authored landmark papers on – among other things – the generation of attosecond pulses, the control of attosecond electron dynamics in strong field ionization, and the observation of attosecond time-scale electron dynamics in molecular systems. Since 2010 Misha is the coordinator of the Marie Curie Initial Training Network CORINF ('Correlated Multielectron Dynamics in Intense Light Fields').

Prof. Mikhael (Misha) Yu. Ivanov

A note on the crisis in Greece

Professor Costas Fotakis is the newly elected President of the Foundation for Research and Technology-Hellas (FORTH), the largest Research Centre in Greece, and has been Director of the Institute of Electronic Structure and Laser (IESL) of FORTH. In this column he gives his view on how the financial and economic crisis affects his country and research at IESL-FORTH.

The present crisis is systemic and, in my opinion, primarily political and it has a European and global character. In Greece it is currently most acute, due to a combination of historic, social and economic reasons. The net effect is that we are witnessing a violent socio-economic restructuring, which is affecting deeply the whole country and of course its scientific landscape. For example, the efforts of the past for reversing the brain drain are cancelled. Talented young researchers consider emigration and it is becoming increasingly difficult to attract prominent scientists from abroad. Severe institutional and financial measures, applied indiscriminately to research organizations, also have a negative effect. None of this is helped by the misinformation and distorted image given by part of the media in Europe.

Under the current conditions, funding for science relies to a large extent on the exploitation of EU structural funds, which may cover short-term needs. For the particular case of FORTH the effects are not so severe as yet. This is because FORTH's major income sources are competitive grants (EU or international) and bilateral contracts with the private and public sectors. However, albeit limited, that portion of state funding is crucial as a catalyst for maintaining FORTH's competitiveness and scientific excellence. This is demonstrated, for example, by the fact that FORTH ranked 12th among the European Research Centres for successful participation in EU projects during 2007-10.

Prof. Costas Fotakis

On a positive side, the crisis has triggered a re-evaluation of research policies, which are now focusing more on exploiting synergies and capacity building. Along these lines, reinforcing the open outlook of FORTH towards effective scientific collaborations and open access is even more important. Strengthening international collaboration, especially the participation of the Institutes of FORTH in ambitious European projects, such as LASERLAB-EUROPE and ELI, are all the more important.

Science for Society

The research conducted within LASERLAB-EUROPE ranges from fundamental science to technology-driven research and applied science. One of the distinguishing characteristics between these types of research is the time it takes for the findings published in scientific papers to find application in society. For fundamental science this delay can be quite long. History teaches, however, that many results from the fundamental science of today might form the basis for solving the 'grand challenges' of society in the future. In contrast with more fundamental types of science, the societal relevance of applied science is usually clear at first sight. For this issue of Laserlab Forum, we selected some projects with applications in a wide range of fields that rightfully deserve the label 'Science for Society'.

Tom Jeltes

Health

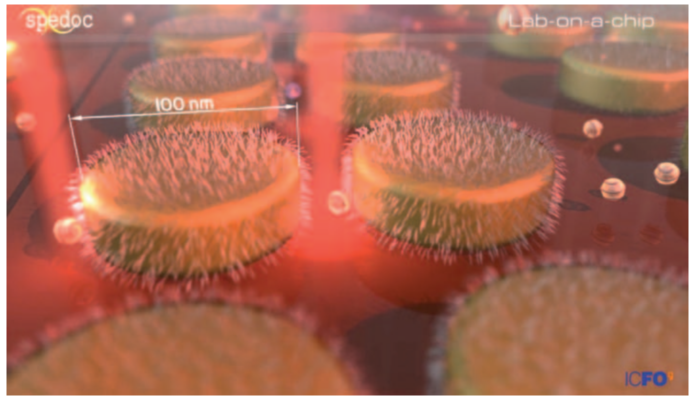
Early detection of cancer | ICFO, Barcelona

In a research programme led by our Spanish partner ICFO, a device is being developed which can detect molecules indicative of cancer with unprecedented sensitivity.

For the treatment of cancer, early diagnosis of the illness is crucial. Recent research shows that specific molecules, called Heat Shock Proteins (HSP), are relatively abundant at the surface of cancer cells and in the patient's blood. Early detection of these cancer markers may therefore allow treatment of cancer patients at an earlier stage of the disease, with lower doses and less secondary effects.

In order to track a low concentration of cancer markers such as HSP70 in the blood, extremely sensitive detection devices are required. At present, such a sensitive device does not exist: diagnosis still relies mainly on macroscopic techniques, with which only tumours composed of several millions of cancer cells can be discerned.

In SPEDOC, an EU-funded research initiative led by the group of Romain Quidant at ICFO, physicists join forces with oncologists to develop a novel ultrasensitive cancer-marking sensing platform for early detection and accurate monitoring during treatment. The device will employ an optical technique called surface plasmon nano-optics to detect the presence of the HSP70 molecule in tiny volumes of blood.



Detection of HSP molecules at the surface of gold nanosensors. © ICFO. Picture by Digivision

Surface plasmons are electronic oscillations supported by, e.g., gold nanostructures. These plasmon oscillations are extremely sensitive to the presence of molecules near the gold surface, and can thus – combined with several other sophisticated techniques - be used to detect HSP70 proteins in blood samples.

The sensors developed in the SPEDOC programme will be implemented on an advanced microfluidics chip. On such a lab-on-a-chip, several laboratory functions are integrated on a chip of only millimetres to a few square centimetres in size. They deal with extremely small fluid volumes down to less than a picolitre – a millionth of a millionth of a litre, roughly the volume of a human cell.

Cultural Heritage

Laser rejuvenation of ancient Greek masterpieces | IESL-FORTH, Crete

Our Greek partner IESL-FORTH has developed a laser system capable of cleaning ancient sculptures. It is currently set up on the visitors' floor of the Acropolis Museum in Athens.

In January 2011, the cleaning laser system was set up on the visitors' floor of the Acropolis Museum, where the Caryatids – sculpted female figures originally serving as columns or pillars – are displayed to the public. Since museum policy is to avoid risky transportation of the precious pieces from ancient Greece, removal of pollution accumulation now takes place under the eyes of the visitors - naturally behind a protective housing.

The laser cleaning technique was selected from over forty competing methods, and has already been successfully used to clean other Athens Acropolis Sculptures - such as the Parthenon West Frieze and the Frieze of Athena Nike's temple.

The laser system is operated at infrared and ultraviolet wavelength simultaneously and can be used to remove thick layers of pollution in a controlled and safe way. The combination of the two wavelengths ensures that the surface of the pieces of art treated is not damaged and the colours are not affected. This unique laser system was developed in close collaboration with the Acropolis Restoration Service and the Ephorate of Prehistoric and Classical Antiquities in Athens.

Laser cleaning of the Caryatids is taking place in situ at their exhibition site in the Acropolis Museum © The Acropolis Museum, Athens, Greece

IESL-FORTH has a long history of developing innovative laser and optical technologies for conservation and diagnostics of works of art. Researchers of IESL-FORTH have developed mobile laser systems that are used to map layers of paint and visualize underdrawings, and laser spectroscopy is employed to identify pigments in paintings, icons and illuminated manuscripts, as well as for analysis of archaeological metal, glass and pottery objects. In a holographic approach, IESL-FORTH researchers use expanded laser beams to uncover effects of deterioration within the structure of objects of art. With this holographic technique, defects that are not visible by other means, including X-ray imaging, become quantifiable.

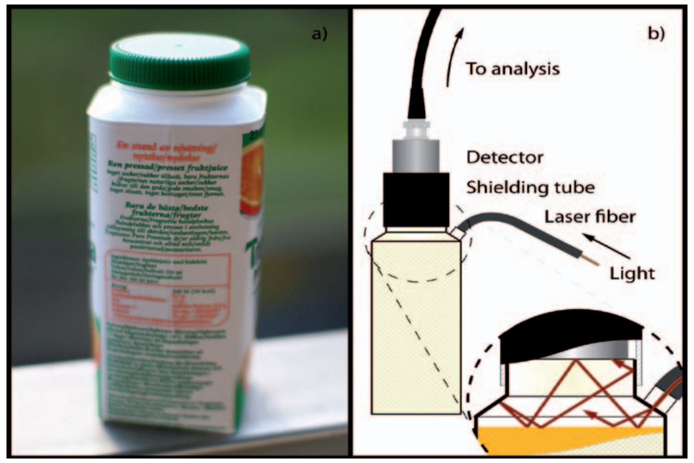
Food

Checking quality of packaged food –from the outside! | Lund Laser Centre

A laser-based, non-intrusive measurement technique developed at Lund Laser Centre could lead to better quality assurance and less waste of chilled packaged foods.

The popularity of fresh, chilled foods – such as packaged fruit juices – Is increasing by the day. In order to slow down deterioration processes and prolong shelf life, traditional packaging methods are being replaced by modified atmosphere packaging: the headspace of the packages are filled with, e.g., nitrogen gas, while the presence of oxygen – which assists in chemical breakdown and microbiological spoilage of the food – is reduced to the minimum

As expiration dates are based on conservative estimates, huge quantities of chilled foods are thrown away daily while the quality might still be up to standard – whereas food that has, e.g., been stored at too high temperatures will still be spoiled before the expiration date. If modified atmosphere is applied, the life time will also depend on the level to which the composition of the head space gas is maintained. Small leaks will lead to an increase in the oxygen content inside the package and thus to a reduced life time. Lack of information on the storage temperature history and headspace gas composition may lead to quality and safety issues. Over the years, many sensing techniques have been developed to check the quality of packaged foods, but almost all of them are intrusive – the package is destroyed and the food is wasted.



Packaged food quality monitoring by laser spectroscopy: A sample of the orange juice packages studied (left), illustration of the detection geometry (right).

Researchers at Lund Laser Centre now have developed a novel, non-intrusive method to measure the oxygen content of the package headspace, called 'gas in scattering media absorption spectroscopy' (GASMAS). In GASMAS, infrared light from a diode laser is sent onto the food package. A small part of the light penetrates into the package, and an even smaller amount of light emerges from it and is detected by a sensitive detector. From the amount of light absorbed inside the package, the oxygen concentration in the headspace can be determined. The Lund researchers believe the GASMAS technique (which has also been demonstrated to be effective in measurements of the lung content of newborn infants and the gas composition in sinuses of adult patients) could be used for 'inline' quality control of packed food items throughout the food packaging supply chain.

M. Lewander et al., Packaging Technology and Science, 24: 271--280 (2011)

Security

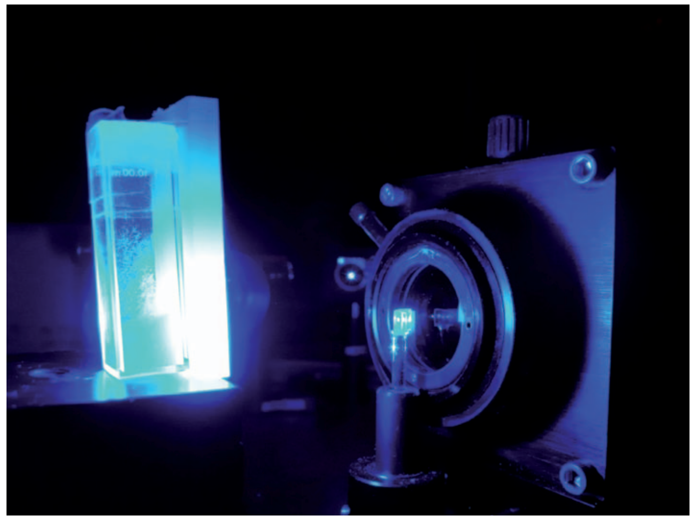
Detection of concealed explosives | LaserLaB Amsterdam

Using a technique called time-resolved Raman spectroscopy, researchers at LaserLaB Amsterdam have been able to detect the presence of DNT (dinitrotoluene), a material found in many explosive materials, through layers of non-transparent plastics.

Detection and identification of explosives and their associated compounds in different environments is a problem of critical interest for security and forensic diagnostics. Many techniques have been investigated for this purpose, but the majority are not ideal for explosives detection in that they are invasive or require lengthy sample preparation. Raman spectroscopy is ideal for the rapid detection of potentially hazardous substances because it is non-invasive and provides a 'molecular fingerprint' that facilitates chemical identification.

Applicability of conventional Raman spectroscopy for investigation of packed compounds is limited, however, as light from the surface layers tends to obscure Raman photons coming from inside the package. In time-resolved Raman spectroscopy, short laser pulses are sent into the object of interest. By carefully choosing the time window in which the returning photons are detected, one can discriminate between photons coming from the surface (the vast majority) and the photons emanating from inside. Thus, using a delay of several hundred picoseconds, only the retarded photons are detected – providing chemical information on the content of the package.

In a project made possible through the LASERLAB-EUROPE Access Programme, the LaserLaB Amsterdam team, in collaboration with Spanish forensic experts from the University of Acalá, has been able to detect the chemical compound



Time-resolved Raman spectroscopy setup; a two layer sample is excited with a 3-ps frequency-doubled Ti:sapphire laser at 460 nm; Raman photons are detected in a backscatter geometry. Photo: Maria Lopez-Lopez

DNT through layers of different diffusely scattering white plastic materials of various thicknesses, including typical non-transparent packaging containers. The association of DNT's with some hazardous and explosive materials makes them of particular relevance for security. For example, they are used in the munition industry as a modifier for smokeless powders, as a plasticizer in propellants, and are products of degradation and impurities in the synthesis of the explosive TNT. Another application area of time-resolved Raman spectroscopy that the LaserLaB Amsterdam team is currently working on is non-invasive disease diagnosis through skin.

I.E. Iping Petterson et al., Analytical Chemistry 2011 83 (22), 8517-8523 (2011)

Science for Society

Energy

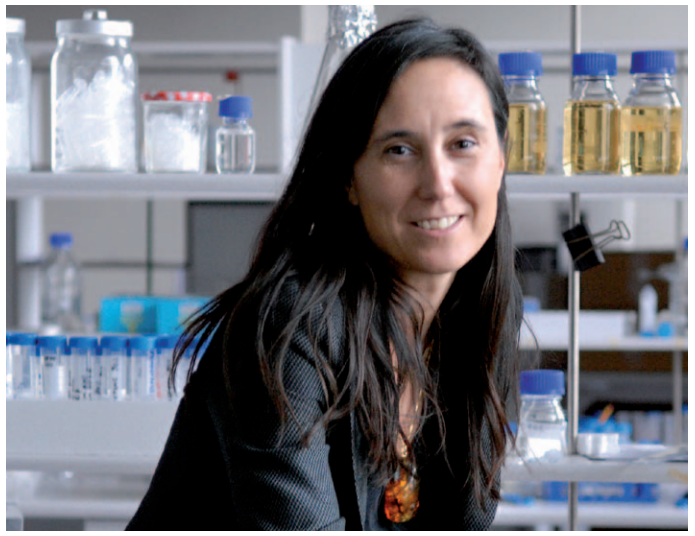
Fuel from sunlight: learning from nature

The Sun is the Earth's primary energy source. The energy stored in fossil fuels is basically stored sunlight - converted to chemical energy by plants and algae millions of years ago. Photosynthesis, the process in which plants and algae use sunlight to create energy-rich sugars from water and CO2, may therefore be key to finding a substitute for the depleting resources of fossil energy. Detailed laser measurements on the absorption of light by the pigments involved in photosynthesis are paramount for our understanding of this life-giving process.

Roberta Croce, professor of Biophysics of Photosynthesis/Energy at LaserLaB Amsterdam since March 2011, is one of the researchers within Laserlab-Europe who are trying to understand the details of photosynthesis in the quest for a sustainable energy source for humankind. Recently, she received an ERC Starting Grant to fund her research.

Croce wants to understand how photosynthesis works for two reasons, she says: "First we might be able to copy nature and build our own photosynthetic systems that can produce fuels from sunlight. But with this same knowledge, one could also manipulate and improve existing systems, such as plants and algae."

The Italian researcher got acquainted with LaserLaB when she visited the lab for a month as part of a Laserlab-Europe Access project. As a professor at Laser LaB Amsterdam, she mainly concentrates on the question how the natural photosynthetic system adapts to changing light conditions.



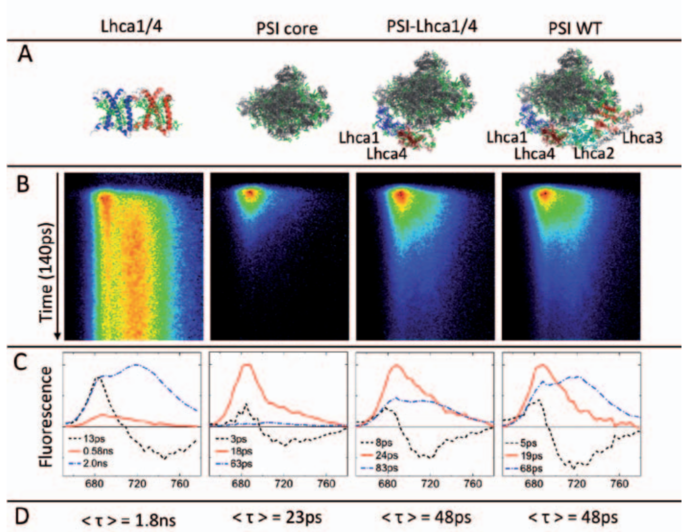
Roberta Croce

At low sunlight, plants crave for every photon reaching their leaves. On the other hand: in full sunlight, plants need strategies to avoid damage due to high light intensities.

Several things can happen with the light a plant receives, explains Croce. The energy contained by the light can be converted to heat, the energy can be emitted again as light with a longer wavelength (fluorescence), it can be stored in sugars (photosynthesis), or it can create so-called free radicals; harmful molecules that will damage the plant from the inside. Croce: "In order to increase the yield of existing crops, whether for food or biofuel, we need to know how we can increase the amount of sunlight used for photosynthesis while avoiding the creation of free radicals."

In the framework of the Dutch national project 'towards biosolar cells', Croce studies high yield carbon fixation plants, which grow up to three times as fast as ordinary plants. This is due to their capacity to handle high light intensities. Croce: "We study those plants in order to find out how they can still use light very efficiently also in very bright light. If we find the mechanisms involved, we might be able to use them to increase the yield of food or biomass from crops."

Croce also collaborates with researchers who grow algae in bioreactors. Those algae could be used either as biomass directly, or could be programmed to produce biofuels. A complicating factor is that – due to the density of algae – only the upper layer of algae is reached by sunlight. "Actually, the upper layer of algae receives too much sunlight, whereas the remainder of the algae see no sunlight at all. To solve this problem, we are looking for ways to decrease the size of the so-called light-harvesting complexes of the algae. That would make the algae more 'transparent', resulting in a more even distribution of light between the algae." In order to accomplish this, part of the proteins from the light-harvesting complex should be removed – but not those proteins essential for the photosynthetic process itself. "We combine genetic modification of the algae with spectroscopic techniques to assess the effect of each modification and to find out which proteins can be safely left out."



Time-resolved (ps) fluorescence experiments on photosynthetic complexes with different antenna sizes.

Croce received an ERC Starting Grant in 2011 to study so-called acclimation mechanisms in algae and plants that allow them to cope with changes in light intensity and nutricients, avoiding photodamage. "Many people study this, but mainly in vitro. It is hard to link those results to what happens in reality." In order to gap this bridge between 'in vitro' and 'in vivo', Croce will use fluorescence spectroscopy to study the behaviour of various types of modified plants and algae. In that way she hopes to find out how the desirable acclimation mechanisms can be promoted.

Tom Jeltes

ERC Starting Grants 2011

The ERC Starting Grants provide important stepping stones for young researchers who are building their own research teams. Grantees receive up to 1.5 million euros to conduct the research described in their proposals. Since the introduction of the Starting Grants by the European Research Council in 2007, around 20 researchers from Laserlab-Europe partners have been awarded a Starting Grant, thereby proving their potential. We introduce four of our 2011 grantees and their research projects.

Dr. Randolf Pohl (MPQ)

Determining the size of the helium nucleus using muonic helium ions

Muonic helium ions consist of a helium nucleus orbited by a single muon instead of an electron. Since muons are about 200 times heavier than electrons, the radius of their orbit is smaller by the same factor. As a consequence, the energy of the orbiting muon is influenced considerably by the charge of the helium nucleus. This provides a means to determine the charge radius of the helium nucleus ten times more accurate than ever before. With his ERC Starting Grant project, 'Charge Radius Experiment with Muonic Atoms', Randolf Pohl hopes to resolve the big discrepancy in the proton size found recently in similar experiments with muonic hydrogen.

Prof. Hugues de Riedmatten (ICFO)

Bringing quantum memories beyond proof-of-principle

Quantum information networks, based on the interaction between light and matter, hold promises for revolutionary advances in information processing, but so far, they have not been taken beyond the proof-of-principle stage. De Riedmatten aims to demonstrate long-lived and robust entanglement between two remote solid state quantum memories, based on rare-earth doped solids. Also, he will try to establish a quantum gate between two qubits stored in ultracold ensembles of laser-cooled Rubidium atoms. Hugues De Riedmatten's ultimate goal within his ERC Starting Grant project Ensemble-based advanced Quantum Light Matter interfaces' is to establish entanglement between the solid-state quantum memory and the cold atomic ensemble. He hopes the results from this project will open new avenues towards the practical realisation of scalable quantum networks and repeaters.

Prof. Morgan Mitchell (ICFO)

Measuring magnetic fields with light and ultracold atoms

Ultracold atoms provide the most sensitive instruments for measurements of time, gravity and magnetic fields, and they are already employed in atomic clocks, gravimeters and magnetometers. Quantum optical effects such as entanglement and squeezing have the potential to improve the sensitivity of these atomic instruments even further. In his ERC Starting Grant project 'Atomic Quantum Metrology', Morgan Mitchell will apply several state-of-the-art quantum optical techniques to measure magnetic fields with ultracold atoms. He aims to test some revolutionary new proposals for quantum metrology, such as interaction-based measurements and quantum compressed sensing.

Prof. Stefan Kuhr (University of Strathclyde and MPQ)

Manipulation of fermions in an optical lattice

Optical lattices created by standing waves of laser light can be used to capture single atoms like eggs in an egg crate. Building on his experience with bosonic atoms in optical lattices at MPQ, Stefan Kuhr will build a similar experiment with fermions. Studying the interaction between individual fermionic atoms, Kuhr hopes he will gain a deeper understanding of the mechanisms leading to macroscopic properties of matter such as magnetism and superconductivity. The ERC Starting Grant project 'Single-atom-resolved detection and manipulation of strongly correlated fermions in an optical lattice' will also help Kuhr establish his new position as Chair on Quantum Information at the University of Strathclyde.

More ERC Grant projects are described at www.laserlab-europe.eu.

Randolf Pohl

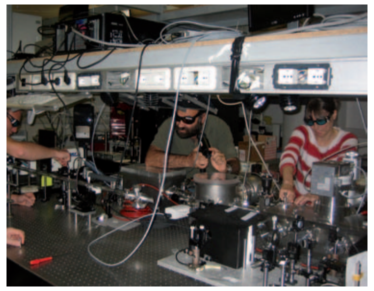
Hugues de Riedmatten © ICFO E Blanco

Morgan Mitchell © ICFO E Blanco

Stefan Kuhr

STELLA 2011:

The experimental summer school in linear, nonlinear and quantum optics



From June 20th, 2011, the 4th meeting of STELLA, the School for Training in Experiments with Lasers and Laser Applications was held in Como, Italy. For three weeks, cutting-edge experiments in modern optics were performed directly in research labs at the Insubria University premises, for training purposes. These concerned femtosecond laser microfabrication (J. Dudley, Besancon), XUV generation (J. Biegert, ICFO), space-time pulse characterization (G. Tamosauskas, Vilnius), SLM beam shaping (M. Padgett, Glasgow), entanglement and Bell inequalities (P. Mataloni, Rome), thermal-light quantum statistics (M. Chekhova, Erlangen), Fourier-space microscopy (R. Cerbino, Milan), random-media speckle frequency correlation (F. Shefford, Fribourg) and single-molecule fluorescence spectroscopy (R. Rigler, Stockholm). A numerical course on femtosecond intense pulse propagation (A. Couairon, Paris and M. Kolesik, Tucson) and a training action on paper-writing were included as well.

STELLA represents the first training event where leading experts from several renowned research institutions gather in a single location, bring their own research equipment with them and share their knowledge about experimental setups, alignment tricks, measurement details, and experimental pitfalls with a number of students, coming from all over the world (Europe, Russia, Canada, South America, India, Australia, Singapore, Iran, etc).

The driving idea behind STELLA is simple, being the same one which has seeded the birth of universities in the Middle Age: the inherent unity between research and education. In other words, the proposed concept of "School" stems from the experience that "a discovery begins when two or more people start sharing it."

In doing STELLA, students, professors, assistants and local organizers have the chance to verify and propose to the international optics community a novel approach to higher-education and research, which de-emphasizes competition among groups in lieu of a true enhancement of knowledge levels. Notably, the proposal is also of interest to laser-optics companies, curious in comparing private research with this open-innovation approach.

On behalf of the organizing committee: John Dudley, Jens Biegert, Ottavia Jedrkiewicz and Paolo Di Trapani

Workshop

"Nonlinear nanostructures for ultrafast laser applications"

Photo: A.Wettstein

Ultrashort laser pulses have developed into an important tool for structuring materials on a micro- and nanometer scale. In parallel, nanomaterials find increasing application in nonlinear optics, plasmonics, and light generation. Most recent results in these areas were presented at the 2nd International Workshop on "Nonlinear Nanostructures for Ultrafast Laser Applications", held from May 19 to 20, 2011 at Max Born Institute, Berlin, Germany. The workshop was jointly organised by MBI, the Competence Network for Optical Technologies in the Berlin-Brandenburg region OpTecBB and LASERLAB-EUROPE. Due to the huge interest, the number of contributions as well as the time scale for the talks had almost doubled as compared to its predecessor in 2009. For the first time, a poster session and presentations of companies were included. More than 120 authors from 10 countries presented their most recent results in 21 oral talks and 8 posters. The scientific program covered selected topics mainly related to laser-induced nanostructures and nonlinear nanooptics. Particular emphasis was placed on nanostructuring of metal surfaces, structuring in three dimensions, multiphoton excitation of semiconductors and dielectrics, plasmonics, nonlinear spectroscopy, and last but not least the characterization of nanomaterials. In his keynote lecture, Prof. S. Sakabe (Kyoto University) spoke about the mechanisms of structure formation on metal surfaces by irradiation with femtosecond lasers. Two other contributions of Japanese colleagues (Prof. M. Hashida, Y. Miyasaka) were dedicated to the same field of interest.

Besides approaches to describe the nanoripple generation at surfaces and in the volume via self-organization and material transport, plasmonic properties of hybrid nanostructures, nanowire networks, 3D-nanoobjects and single nanorods were discussed. MBI presented most recent results on the nonlinear optics of plasmonic structures (higher harmonic generation, saturable absorption, multiphoton channels of ultrashort-pulse nanostructuring, coupling of local nanostructures to organic layers) as well as experiments on the dynamics (time-resolved characterization). The workshop was rounded off by two laboratory visits at MBI and the neighbouring Leibniz Institute for Crystal Growth (IKZ) and an evening get-together meeting. A book with the best contributions is in preparation to be edited by Springer Publishers. The book of abstracts in pdf format is available for download on the event's webpage at www.laserlab-europe.eu (events 2011).

Rüdiger Grunwald

CRASY spectroscopy plays with quantum physics

A novel spectroscopic method for the simultaneous measurement of molecular structure and composition, called CRASY, has been developed at the Max Born Institute (Berlin). The work has been reported in Science.

Scientists can play with a large set of spectroscopic tools when they wish to analyze specific properties of molecules. Rotational spectroscopy, for example, can resolve different molecular structures, because each molecule rotates with a characteristic set of frequencies. Mass spectrometry can determine the mass of a molecule and its fragments, and therefore offers information about the atomic composition of the sample. To date, experiments such as rotational spectroscopy or mass spectrometry were only performed separately. The method of Correlated Rotational Alignment Spectroscopy (CRASY) now allows the simultaneous ("correlated") measurement of both, atomic composition and molecular structure.

CRASY experiments resolve mass and structure of inseparable compounds simultaneously, such as the depicted CS2 isotopes. © MBI

To perform this experiment, the scientists used an experimental trick: they first used an ultrashort laser pulse to initiate a rotational motion in each molecule of a molecular ensemble. After a short time, a second laser pulse was used to remove an electron, i.e., to ionize the molecules. The mass of all molecular ions was then determined in a mass spectrometer. The rotational motion turns the molecules in space ("rotational alignment"), and thereby affects the probability to ionize. When the molecules are allowed to rotate for different amounts of time, the rotational motion is directly reflected in the number of detected molecular ions and the rotational frequencies can be calculated.

With the simultaneous determination of rotational frequencies and masses, the researchers overcame the limits of the individual spectroscopic methods and obtained correlated information on molecular structure and atomic composition.

"CRASY experiments contain much more information than conventional spectroscopic experiments, because the information content scales as the product of that in individual experiments", claims Thomas Schultz from the MBI. This should permit the investigation of increasingly complex systems. The researchers first demonstrated their technique with the analysis of rotational constants for ten isotopes in a natural carbon disulfide sample. In a single experiment, they were able to reproduce all rotational constants in the literature and to determine three additional constants, which were previously inaccessible by spectroscopic measurements. "As compared to conventional rotational spectroscopy, we only require minute amounts of sample and the sample can be highly impure", continues Schultz. In the future, the researchers plan to use CRASY experiments for the analysis of photochemical reactions in DNA bases.

Christine Vollgraf

Science 333 (6045), 1011-1015 (2011)

Unique source of gamma rays

At the Central Laser Facility (CLF), a team led by Prof. Dino Jaroszynski from the University of Strathclyde has demonstrated the brightest gamma ray beam ever created. The gamma rays could be a powerful tool in cancer therapy or security scans.

Prof. Dino Jaroszynski

The researchers have found a way to produce a bright, high energy X-ray or gamma ray source, much more energetic than those commonly used in radiology. The special properties of these X-rays make them ideally suited to producing high resolution images in medical applications. The results could pave the way for systems that will reveal far greater detail than is possible at the moment.

The gamma rays were produced focussing a laser beam into a tube of plasma, which is formed by ionising hydrogen. Electrons are trapped in the ion-cavity formed behind the laser pulse and accelerated to high energies. They pick up energy from the laser much in the way that a child picks up kinetic energy on a swing. This gives rise to an intense beam of gamma ray photons with energies of many thousands to several millions electron volt.

Silvia Cipiccia

Some of these gamma-rays are so intense that they can pass through 20 centimetres of lead and would take 1.5 metres of concrete to be completely absorbed. They are also strongly polarised (like a laser) and are emitted from a very small area which makes them ideal for use in high resolution medical imaging where structures such as hairline fractures are often invisible using conventional X-rays.

Until now, such high energy X-rays could only be produced at high cost using accelerators that are 100s of metres in size. This breakthrough opens the way for systems that could be much more compact and produced at reduced cost. Screening for disease and for illegal goods in transport are just two potential applications.

Silvia Cippiccia et al., Nature Physics 7, 867--871 (2011)

Research Collaboration: Staged laser ion acceleration

A novel method to actively modulate the energy spectrum of laser-accelerated protons has been investigated experimentally in a collaboration of the LASERLAB-EUROPE partners Rutherford Appleton Laboratory, MBI and IOQ Jena. Using a staged acceleration scheme, the transient electric fields generated in the second acceleration stage could actively be used to modify the spectrum of the protons coming from the first acceleration stage. This method offers the possibility to tailor laser-generated proton spectra for future applications.

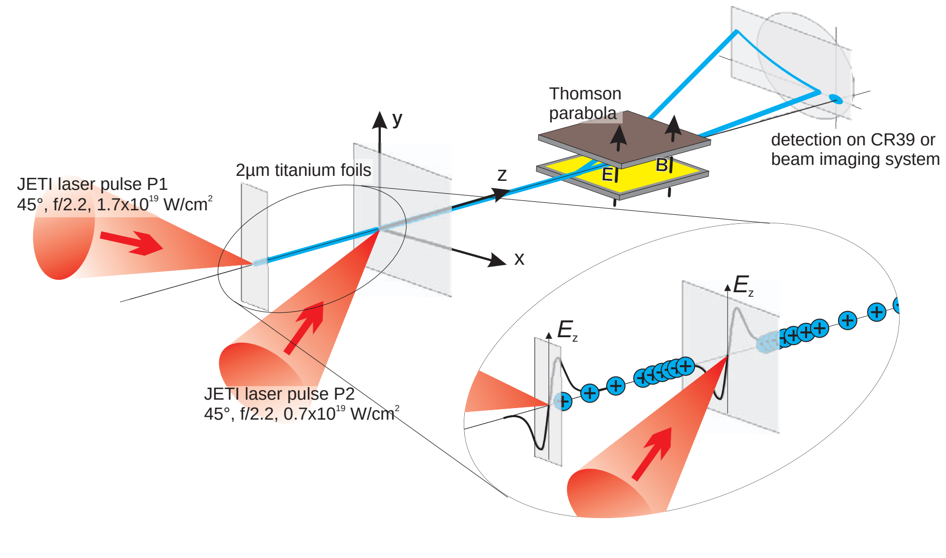


Fig. 1: Sketch of the experimental setup for staged ion acceleration

The acceleration of particles from plasmas generated during high-intensity laser-matter interactions is a rapidly developing field. Significant progress in the development of table-top high-power laser systems has opened up the possibility to accelerate electrons, protons or heavier ions to MeV or even GeV energies over distances of micrometers to centimeters which are much shorter than those required in conventional accelerators. For the acceleration of ions from thin, laser-irradiated metal foils, the process of Target Normal Sheath Acceleration (TNSA, [Wilks01]) has been studied extensively over the past decade [Fuchs06].

However, to fully exploit the potential of this laser-based source of ion radiation for a number of envisaged applications, a full control over the parameters of the generated ion pulses is mandatory. Above all, the possibility to shape and actively control the energy spectrum is of primary interest. In a collaboration between the Rutherford Appleton Laboratory in the UK, the Max-Born-Institute in Berlin, and the Institute of Optics and Quantum Electronics in Jena, Germany supported by LASERLAB-EUROPE, we have developed and verified a novel technique based on a cascaded acceleration scheme which gives us control over the shape of the energy spectrum [Pfotenhauer10].

The TNSA mechanism has proven to be an efficient and highly reliable process for the acceleration of ions from laser-plasma interactions. Here, positive ions stemming from contaminations on the target surface are accelerated by the electric field which has been set up by the separation between laser-accelerated, relativistic electrons and the positive ions themselves. Protons, having the highest charge to mass ratio, are accelerated predominantly. This process usually produces broad, temperature-like energy spectra of the ions. As a consequence of the broad spectrum, the initially short ion pulse (having durations of the order of a few times the laser pulse duration) is temporally broadened due to the different velocities of the different ion energies.

A spectrum exhibiting narrow, quasi-monoenergetic peaks can, in contrast to the basic TNSA approach, be obtained e.g. by using micro-structured targets [Schwoerer06, Pfotenhauer08]. Another approach is to start with a broad spectrum from a TNSA process and separate the process of its shaping by applying an appropriate transient electric field distribution after the initial acceleration has terminated. This second electric field could then accelerate or decelerate different fractions of the proton population eventually concentrating a higher number of protons in a certain energy range, i.e. forming a peak in the spectrum.

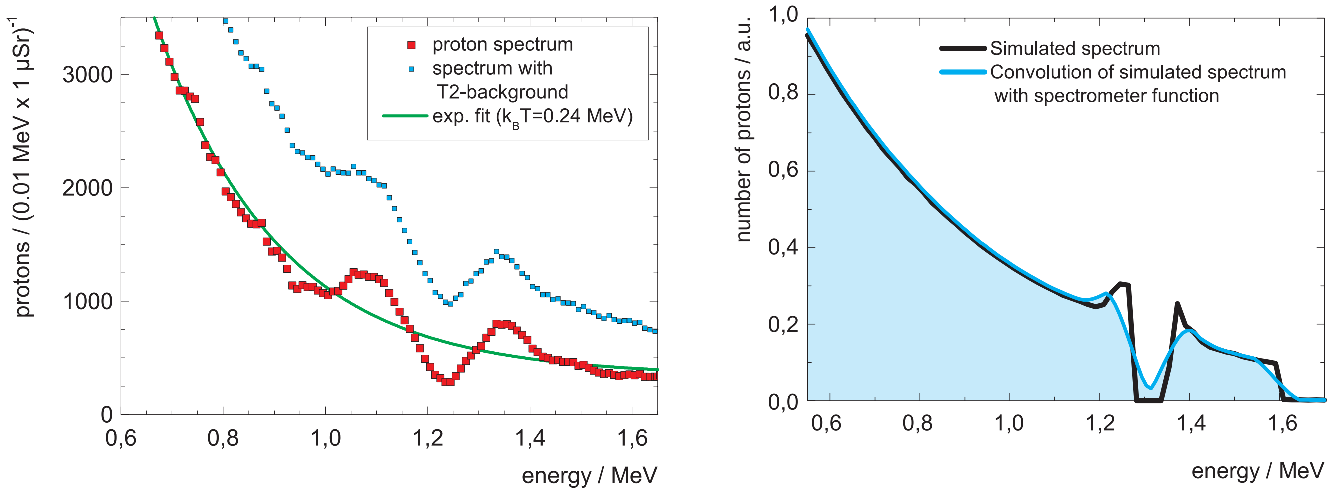


Fig. 2: Measured (left) and simulated (right) proton spectrum after double-stage acceleration.

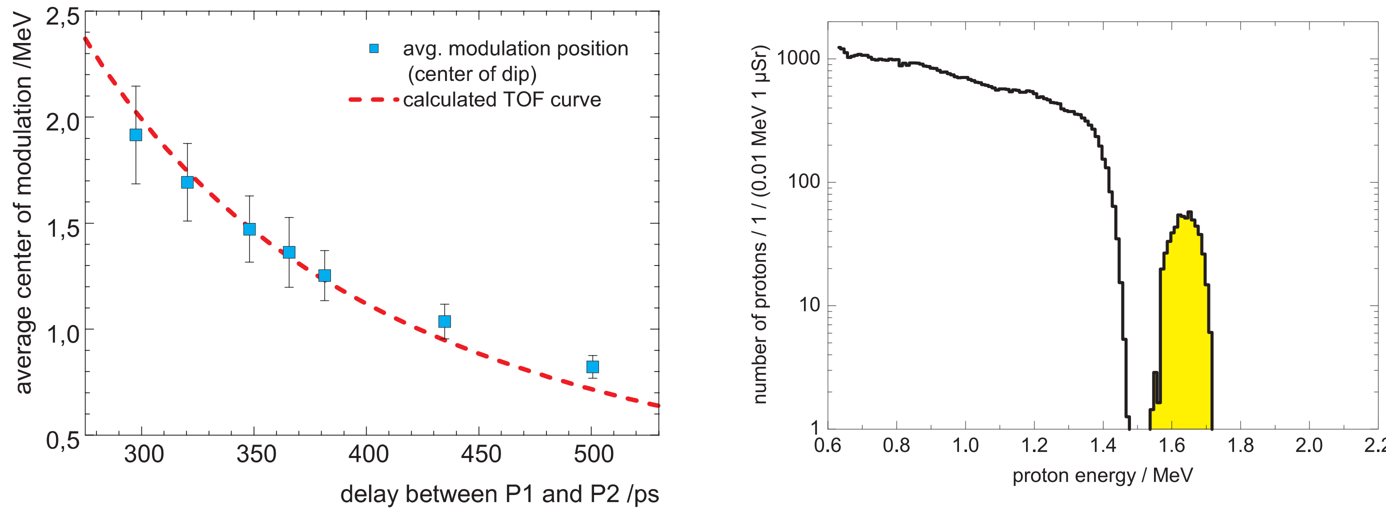


Fig. 3: Central energy of modulated part of the proton spectrum as a function of the delay (left) and generation of a free-standing, quasi-monoenergetic peak in the spectrum using the staged acceleration scheme.

By carefully adjusting the timing between the proton pulse and this second electric field, different parts of the spectrum can be affected giving us active control over the energy spectrum. While a transverse electric-field distribution can be applied using a laser-driven micro-lens [Toncian06], a longitudinal field distribution can be generated by triggering a second, laser-driven TNSA field on a second, separate target foil with a second laser pulse [Pfotenhauer10]. By using a fraction of the driving laser pulse which is focused to the second target an intrinsic synchronization between the two interactions leads to a very robust and reliable technique to shape the energy spectrum.

The experiments have been carried out using the JETI laser facility at the Institute of Optics and Quantum Electronics in Jena, Germany. Being part of the Access Programme of LASERLAB-EUROPE, the JETI laser offers experimental beam time to external users. At the time of the experiments described here, JETI was delivering 10-TW laser pulses to the target containing a total energy of 0.8 Joule within a duration of 80 fs at a repetition rate of 10 Hz.

Before the interaction, the laser pulses were split in two (P1 and P2) using a 60/40 beam splitter. The stronger pulse (P1) was focused using a parabolic mirror onto a first, 2 μm thick Ti foil coated on the rear surface with PMMA plastic to generate a broad-energy proton pulse via TNSA. This proton pulse propagated towards a second 2 μm Ti foil which was mounted parallel to the first foil in a distance of 5.86 mm. During this propagation, its duration increased due to the different velocities of the protons. When reaching the second foil, the second part of the JETI pulse (P2) being focused by a second parabola initiated a second, transient TNSA field which acted as the modulating field. The delay between the two laser pulses could be varied using a motorized delay stage. The energy spectra of the proton pulses could be measured using a Thomson parabola (cf. Fig.1).

As mentioned above, the interaction of the second pulse (P2) with the second foil initiates a transient, longitudinal electric field which affects the energy distribution of the proton pulse coming from the first foil. Since this electric field is generated on both surfaces pointing away from the target in both cases, slower protons still being on the front surface are decelerated (here, the electric field lines point in the opposite direction of proton propagation). However, protons which have already passed through the second foil experience an additional accelerating field on its rear surface and are hence shifted to higher energies (cf. Fig. 1).

This process leads to a characteristic depletion in the resulting proton spectrum at a central energy and the formation of two neighboring peaks at lower and higher energies, corresponding to protons which have been decelerated and accelerated, respectively (cf. Fig.2). The central energy in the depleted region corresponds to the protons having a time of flight between the two foils equal to the delay between the two laser pulses. By appropriately choosing the delay between the two laser pulses, the position of the depleted region could be shifted to the cutoff energy of the proton population of the first foil. This additional acceleration of the high-energy protons led to the formation of a free-standing, quasi-monoenergetic peak in the proton spectrum as shown in Fig. 3, right.

In conclusion, we have experimentally demonstrated that it is feasible to actively modulate the energy spectrum of a proton pulse initially having a broad, temperature-like energy distribution employing a staged acceleration setup. Since it is vital for various applications to have a tailored particle spectrum available, we will further investigate this approach in the future. Furthermore, information on the temporal anxd spatial distribution of the electric field on the second foil can be extracted from the affected proton pulse. Hence, our method can also be used as a longitudinal proton probe for laser plasma interactions.

Malte C. Kaluza, Jens Polz, and Oliver Jäckel

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Forthcoming events

3rd Annual Meeting NAUUL - Science with PW-class lasers
Paris, France 23-24 January 2012

LASERLAB User Meeting
Szeged, Hungary
16-17 February 2012

LASERLAB Joint JRA Meeting
Bratislava, Slovakia
14-15 March 2012

LASERLAB General Assembly Meeting
Bratislava, Slovakia
15-16 March 2012

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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HiPER Making Progress

The HiPER preparatory phase has been extended to April 2013 to maintain continuity until "First Ignition" at the National Ignition Facility (NIF) in California. HiPER partners are continuing to develop bids to national funding agencies under the EU banner.

Following the Executive Board decision that HiPER will focus on shock ignition, partners are now discussing an experimental strategy using large scale facilities in UK, France and the U.S., to culminate in full-scale ignition experiments at Laser Mégajoule (Bordeaux) and NIF during HiPER's next phase.

In Spain, "Techno-Fusion" has been announced. This broad-based materials technology programme will benefit both Inertial Fusion Energy and Magnetic Fusion Energy communities, exploiting important synergies between the two approaches. Funding is also being sought under the ESFRI roadmap for a new laser facility to examine first wall materials. In Italy funding has been allocated for computational studies at the University of Rome while, in Frascati, the ABC laser will be available to HiPER researchers. Ratification is awaited of the Greek Government decision to support participation in the next phase of HiPER, with €3M requested.

In the UK, STFC has established the Centre for Advanced Laser Technologies and Applications (CALTA) to develop high average power, high repetition rate lasers. The DiPOLE project is already achieving 6J / 10Hz, with 10J / 10Hz expected soon. DiPOLE aims to demonstrate technology scaleable to 100J / 10Hz regimes and beyond.

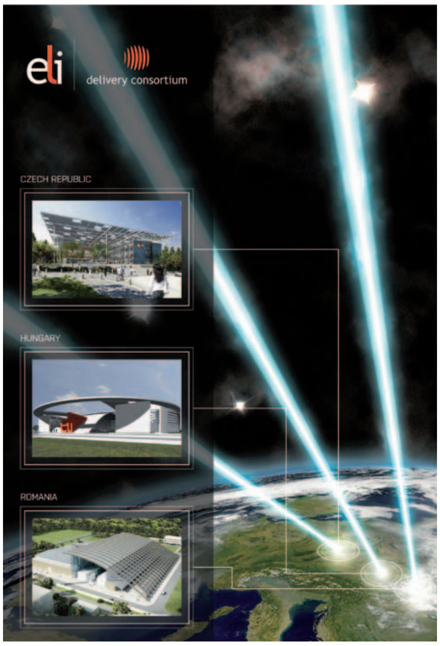
With First Ignition on NIF approaching, HiPER must be ready to meet the challenge of repetition rate Laser energy. The Preparatory Phase has produced a well-founded project ready to proceed with design and construction of technology prototypes and, ultimately, a demonstrator capable of delivering base-load electricity to the grid.

The next HiPER participants' forum will be held at the Hôtel de la Région, Bordeaux on 2nd February 2012.

John Parris

ELI – Getting partners on board

The Extreme-Light-Infrastructure (ELI) needs strong capacity at the European level to develop as a truly integrated and inclusive initiative and ensure optimal use and sustainable access to the resources it needs. The establishment of the ELI Delivery Consortium (ELI-DC) as an autonomous



Courtesy of ELI Beamlines

legal entity – an international association – and the recruitment of a permanent European management and administrative team are the two immediate steps on the agenda of the Czech, Hungarian and Romanian hosts to answer this urgent need (see issue 11 of Laserlab Forum for more details on the ELI-DC).

On the occasion of a meeting held in Budapest on 14 November, where nearly 10 countries were represented, the three hosts confirmed their readiness to incorporate the ELI-DC as well as their strong willingness to see other countries join soon as legal members of the new entity. In addition, they announced the launch of the selection process for the positions of Director General and Scientific and Technical Director of the Delivery Consortium. Supported by a search committee involving international experts, the three hosting countries expect to finalise recruitment in the first few months of 2012.

Florian Gliksohn