LASERLAB-EUROPE

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Work package 4 – Scientific and Technological Exchanges

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Final report on “Collaborative Experimental Programs”

Lead Beneficiary: 3 CEA-SLIC, in collaboration with the Laserlab Networking Board

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PU = Public PP = Restricted to other programme participants (incl. the Commission Services) RE = Restricted to a group specified by the consortium (incl. the Commission Services) CO = Confidential, only for members of the consortium (incl. the Commission Services)	PU

1 Introduction and objectives

Each member of the Laserlab-Europe Consortium possesses unique expertise in some domains of laser science and technology and infrastructure management. At the consortium level, the sum of this expertise is outstanding; at the individual level, the sharing of expertise benefits many members and increases the overall effectiveness of the Laserlab-Europe Consortium. The objective of this work package is to pool this distributed know-how and good practices concerning essential practical issues such as security, laboratory management and data acquisition procedures, as well as crucial scientific issues of relevance for many Laserlab-Europe participants. The outcome of this scientific and technological networking will be increasingly unified efforts from all members of the Consortium, pushing forward laser science and technology in the European Community at large.

2 Task 2: Collaborative Experimental Programs

Task leader: CEA-SLIC in collaboration with the Laserlab Networking Board

The objective of this scientific and technological networking task is to increase the unified capacities of all members of the Consortium, pushing forward laser science and technology in the European community at large. To this end, this activity provides the general framework to help and encourage the organisation of intra-consortium staff exchanges, with two different lines of action:

2.1 Task 2a) Staff exchanges

Staff exchanges particularly focus on technical training and exchange of technical know-how and best practices, and address primarily technical staff. During the lifetime of the project, Laserlab has issued four internal calls for applications from Laserlab scientists or technicians for staff exchanges. For the evaluation of the applications a Project Selection Panel, composed of representatives of the different Laserlab boards and one User Representative, was set up. Proposals were evaluated in view of the following criteria:

- Relevance of the objectives of the exchange and the needs of the sending institution;
- Appropriateness of the approach as well as of the host with respect to the objectives of the exchange;
- Qualification of the staff to be exchanged.

In each proposal the applicants explain how the proposed visit(s) will lead to important transfer of knowledge and/or good practice between partners of Laserlab-Europe. Out of the 26 applications received, 17 were found to be well justified and perfectly in line with the aims of the call and were selected for implementation. 28 technicians and scientists from 10 labs benefited from the training at nine different host labs.

The following intra-consortium staff exchanges were performed:

i) CLPU – CLF

Sending Institution: Centro de Laseres Pulsados Ultracortos Ultraintensos, Salamanca, Spain

Hosting Institution: Central Laser Facility, Rutherford Appleton Laboratory, STFC, UK

Duration: 4 weeks

Participating staff: Ricardo Torres, Luca Stockhausen

Objectives of the exchange: The objective of this exchange is to acquire hands-on experience on the implementation and operation of an experiment of proton acceleration in laser-plasma interactions. In particular we want to learn techniques for control of the pulse contrast, target alignment, plasma characterization, and proton detection. We intend to achieve these objectives by spending four weeks in the Central Laser Facility, at the time that Prof. Paul McKenna's team, from the University of Strathclyde, will be running an experimental campaign with the Gemini Laser. This exchange will also help to establish a collaboration between CLPU and the University of Strathclyde on laser ion acceleration.

The Pulsed Laser Centre (CLPU) is a new research facility established in 2007 with the purpose of building and operating a petawatt laser system (Vega) for national and international users.

The Vega laser will begin operations with 100 TW of peak power by late 2013. In its final phase it will be distinguished worldwide for its short pulse duration (30 fs) and high repetition rate at the petawatt level (1 Hz). As Vega will be the first ultrahigh intensity laser to become operative in Spain, it is expected to open new research lines in the country and bring new experimental opportunities to a community that had no previous access to this kind of science.

One of these lines of research is laser plasma acceleration and applications of laser-generated particle beams. The idea of CLPU is to generate secondary beams of protons, ions, electrons or X-rays, and make them available to the user community for research in materials science, inertial confinement fusion, or cancer therapy among many other applications.

However, the novelty of this technology in Spain also means that there is a lack of local expertise and know-how. The staff exchange programme of Laserlab thus becomes extremely important for us, and it is an ideal opportunity for CLPU to boost this strategic line of research in laser plasma acceleration and for the whole community to develop a technology with such potential impact.

Achievements: This staff-exchange programme has given us the chance to acquire hands-on experience in setting up and conducting an experiment of laser ion acceleration in a high-power laser facility. These experiments are extremely complex and the only way to get the right training on their operation is by attending an actual experiment being carried out by an experienced group. This is exactly the opportunity that has offered us the group of Paul McKenna, of University of Strathclyde, in the Vulcan Target Area Petawatt of the Central Laser Facility - STFC.

We have been trained in the multitude of diagnostics that are used in laser-plasma experiments, their design, setting-up, operation and analysis. In particular we have got an in-depth training with Thomson parabola spectrometers, where we have practiced image plate processing and analysis of ion tracks. We have also learnt about the stacks of radiochromic films and how to design them using a software to calculate the stopping power of different materials. We have familiarised with the other diagnostics as well, including an electron spectrometer, a shadowgraph, a Mach-Zehnder interferometer, a Nomarski interferometer, optical spectrometers, and far field and near field imaging in back scattering and transmission.

Furthermore we closely followed the target alignment and change-over procedures in between shot cycles and have gained valuable knowledge about data acquisition and the local safety and radioprotection rules.

Overall this staff exchange provided us with an ideal training, because all this is very valuable and necessary for the development of the experimental capabilities of CLPU.

ii) CLPU – LOA

Sending Institution: Centro de Laseres Pulsados Ultracortos Ultraintensos, Salamanca, Spain

Hosting Institution: Laboratoire d'Optique Appliquée, Palaiseau, France

Duration: 4 weeks

Participating staff: Camilo Ruiz Méndez, Andreas Döpp

Objectives of the exchange: The aim of this staff exchange is to acquire technical skills and knowledge about experiments on PW class laser-driven electron acceleration. This visit aims for a detailed exchange of knowledge concerning different parts of the experiments, i.e. planning, setup, diagnostic, operation and analysis.

As CLPU's Multi Terrawatt Laser system Vega phase 2 is expected to be ready for experimental usage in late 2013, we are currently in the planing phase for the setup of first experiments on laser wakefield acceleration (LWFA). Within Laserlab-Europe LOA is one of the institutions with the longest tradition and this is why it will be highly advantageous for the scientist at CLPU to spend some time there to learn from them about technical details, both on the setup itself as about the diagnostics. Beside their long experience in LWFA, the new Salle Jaune laser system is a double beam system, which allows to perform experimental configurations similar to the phases 2 and 3 in Vega, currently in construction at the CLPU site. In this phase of the project an intense exchange is crucial in order to provide the best design of the Vega target area and experimental setup, all efforts to improve the setup for underdense targets in Vega will impact in the scientific output of this user facility.

Achievements: The staff exchange activities took place in two visits, the first one in June 2013 to learn on the techniques of detection of X-rays and to participate in an experiment of Compton Scattering at Salle Jaune in LOA. The technique developed at LOA (K Ta Phuoc, Nature Photonics 2012) has shown to be the easiest to implement and very robust allowing the production of a bright X-rays pulses with energies in the range of 100 KeV.

The second visit took place in November/December 2013, to perform a series of simulations of our next experiments. During these three weeks Camilo Ruiz Méndez has been working with Dr. Kim Ta Phuoc and Dr. Agustin Lifschitz using the PIC code CALDER to simulate the collision of two high power laser pulses. The simulations aim to provide a parameter range for the experiment that will be performed later this year at LOA. The objective is to inhibit the plasma wake to increment the oscillation of the electron in the bubble and enhance the betatron radiation produced. The results have been satisfactory and these parameters will be used to perform the experiments.

The exchange has proven to be a very valuable tool to implement the collaboration and to finally exchange knowledge from an institution with long experience to a young institute as CLPU. The collaboration between LOA and CLPU will continue over time and the scientific result from the collaboration will be of great value for both institutions. The exchange produced in these visits has allowed a deep insight into the things CLPU has to put in place to make our installation successful.

iii) IST – CLF

Sending Institution: Instituto Superior Técnico, Group for Lasers and Plasmas, Lisbon, Portugal

Hosting Institution: Central Laser Facility, Rutherford Appleton Laboratory, STFC, UK

Duration: 2 weeks

Participating staff: Gonçalo Figueira

Objectives of the exchange: To acquire practical know-how in the following areas:

- daily set-up and operation of an ultra-high power laser (Vulcan PW)

- related pulse and beam diagnostics, large aperture beam alignment

- shot data management and storage

IST operates a 20 TW Ti:sapphire / Nd:glass laser system, which has considerable internal demand. Currently, a new, larger facility is being designed, which will host an upgraded version of this laser system and multiple target areas. The upgrade will consist in the addition of an existing 64 mm rod amplifier, capable of increasing the power beyond the 50 TW level, a larger vacuum compressor chamber and gratings, and a new target area.

This upgrade will be the most significant change to the configuration of the laser chain of the last years, and it must be accompanied by a number of improvements at the level of reliability, control, and beam and pulse diagnostics. The overall objective is to maximize the number of successful shots, develop an integrated and reliable suite of diagnostics, and implement tested and successful mechanisms for managing and storing the shot data. It is expected that these measures will allow a faster experimental turnover and a streamlined, more successful use of the facility at IST.

The Vulcan PW laser at the CLF is a world-leading, state-of-the-art facility, operating at the same wavelength (1053 nm) and a similar pulse length (~500 fs) as the system in Lisbon. This is especially important since the practical know-how for spectrum and pulse diagnostics can be easily shared, and a fruitful interaction can be easily built on that common expertise.

Achievements: The exchange took place during a period of maintenance of the Vulcan PW laser system. This was chosen specifically to allow full access to all the stages of the laser system. I joined the Vulcan Laser Team and had the opportunity to interact with several members in a number of the maintenance activities. Below is a summary of the highlights of the exchange period.

- Vulcan laser operation

I learned about the daily procedures for starting, aligning and optimizing the laser system, and compared with my own experience on these aspects. I discussed the application of the alignment tools used, from iris diaphragms to movable crosshairs and compact CCD/CMOS cameras.

I discussed issues such as the stability of the laser system over daily operation, thermal management and vibration, or the influence of air-conditioning in the stability of the high power shots. I followed the full procedure for a high power shot, from interaction with the users, setting up the desired parameters, safety precautions before a shot, and recording and analysis of the results.

I also had the opportunity to learn about recent developments in the crystal testing facility of relevance to future OPCPA upgrades in Vulcan.

- Short pulse diagnostics

I was introduced to the different types of autocorrelators being used for the Vulcan PW laser. I discussed the pros and cons of each type. In particular, I discussed a recent model of autocorrelator with a very large temporal window, which has proved very successful for measuring pulses 100's of fs long. I had the opportunity to visit and evaluate the TAP diagnostics, in particular the recent ones for a low B-integral, sub-aperture beamline, sampling a small fraction of the large PW beam from a small hole in one of the final mirrors before the target. I evaluated some recorded shots and compared the measurements given by an autocorrelator and a GRENOUILLE diagnostic. I analyzed and discussed features present in the temporal measurements, and tried to correlate those with known nonlinear effects and uncompensated dispersion.

- Shot data management and storage

I learned about the type of data acquired for each shot and the several software options tested over the years. I discussed several hardware issued related to using a large number of diagnostics. I also compared the treatment of autocorrelation results with my own practice.

- Workshop 'Characterisation of ultra-short high energy laser pulses'

This Laserlab-Europe workshop took place during the period of my stay. The workshop was very interesting, with a lively exchange of ideas and know-how for characterizing short laser pulses. This gave me additional opportunities to learn about techniques and best practices used at other facilities.

Overall this was an extraordinary opportunity for exchanging practical know-how in high power laser operation, which provided me with a renewed insight into many aspects of my own laser facility.

iv) IST – ICFO

Sending Institution: Instituto Superior Técnico, Group for Lasers and Plasmas, Lisbon, Portugal

Hosting Institution: The Institute of Photonic Sciences, Barcelona, Spain

Duration: 2 weeks

Participating staff: Hugo Pires

Objectives of the exchange: To acquire practical know-how in the following areas:

- design and operation of a mid-infrared (MIR) OPA laser chain

- daily set-up and operation of a MIR laser

- specifications and diagnostics for ultra-broadband pulse compression at the MIR range

The laser R&D team at IST is currently assembling an OPCPA chain based in the nonlinear crystal YCOB, pumped by the frequency doubled output of a multipass Yb:YAG amplifier (100 mJ, 1030 nm, 1 Hz), and seeded by a supercontinuum spectrum. The expected output parameters of this ultrashort pulse chain are 20 mJ / 20 fs / 1 Hz, with a bandwidth extending from 700-900 nm.

The idler of the OPCPA stages is a broadband pulse in the mid-infrared extending from 1.2 – 2.0 µm. This spectral range has recently attracted much attention because of its favourable properties for the study of phenomena such as high order harmonic generation or ultrafast spectroscopy. However the IST group has no previous practical experience working in this wavelength range. Although it is feasible to implement a new ultrashort source derived from compressing the idler of the OPCPA system, it would be much more efficient to acquire previous know-how about the optics, diagnostics, etc from a group with recognized experience.

The Attosecond and Ultrafast Optics group at ICFO has recognized expertise in the development of high-average-power, CEP-stable, few-cycle sources in the mid-infrared, making it an excellent partner for the purposes of this staff exchange.

Achievements: The exchange took place during a period of maintenance of one of the laser chains of the ICFO-Atto laser system. This was chosen specifically to allow full access to all the stages of the laser system. I joined the Laser Team and had the opportunity to interact with several members in a number of the short maintenance, development and characterization activities. Below is a summary of the highlights of the exchange period.

- mid-IR compression and diagnosis

I learned about the suitable materials and techniques for aligning, compressing and characterizing a laser system operating beyond the 1.2 microns, and compared with my own experience on these aspects. I discussed the available options for prism pairs, spectrometers and screen cards. I built a gratings compressor and tested the compressibility of a 1.5 micron beam, also measuring its astigmatism.

- Electronic beam synchronization

I was introduced to the aspect of electronically synchronizing a laser chain with its pump system, learned on the implications and saw first-hand the consequences of such a system. I had the opportunity to learn the physical and the computer implementations of the synchronization system, and was tasked to try to integrate the system to a more compact and autonomous performance.

- OPCPA optimization in periodically poled crystals

I learned about the type non linear crystals used to amplify laser pulses at ICFO. I discussed several considerations on the usage of such crystals and performed a bandwidth and efficiency study for some crystals that had yet to be studied.

- Novel laser chain modeling

During my stay I was tasked with assisting the modeling for a mid-IR system and performed simulation leading to the calculation of the sizes for the crystals to be bought to create the system as well as the expected outputs at each OPCPA stage of the chain.

Overall this was an extraordinary opportunity for exchanging practical know-how in high power laser operation, which provided me with great knowledge and awareness of the main difficulties of developing and working with mid-IR laser system, which will help greatly in many aspects of my work in my own laser facility.

v) CLPU – CELIA

Sending Institution: Centro de Laseres Pulsados Ultracortos Ultraintensos, Salamanca, Spain

Hosting Institution: Centre Lasers Intenses et Applications, University of Bordeaux, CNRS, Bordeaux, France

Duration: 2 x 4 weeks

Participating staff: Enrique Garcia, Oscar Varela

Objectives of the exchange: The objective of this exchange is to acquire hands-on experience on the diagnostics development for measuring spatial chirps after compressors and laser development for fiber lasers.

The Pulsed Laser Centre (CLPU) is a new research facility established in 2007 with the purpose of building and operating a petawatt laser system (Vega) for national and international users. The Vega laser will begin operations with 150 TW of peak power by beginning 2014 and main PW line installation will also take place all over 2014. In its final phase it will be distinguished worldwide for its short pulse duration (30 fs) and high repetition rate at the petawatt level (1 Hz). As Vega will be the first ultrahigh intensity laser to become operative in Spain, it is expected to open new research lines in the country and bring new experimental opportunities to a community that had no previous access to this kind of science. However, the novelty of this technology in Spain also means that there is a lack of local expertise and know-how. The staff exchange programme of Laserlab thus becomes extremely important for us, and it is an ideal opportunity for CLPU to boost the knowledge of the technical group in laser skills that will be very important for the installation and future development of the center.

Achievements:

a) Enrique García has realized his stance under the supervision of Stephane Petit from CELIA. During the exchange at CELIA laboratories, Enrique Garcia has realized two main tasks. First he learned how to align and optimize a Treacy pulse compressor. Later, using the grating compressor to control/induce spatial chirp, he measure/correct the spatial chirp by using several methods. He also assisted to some laser system maintenance with the kHz system Aurore. All the work related with the spatial chirp was made with Eclipse system, a 10 Hz, 30 fs, multi-terawat laser. Nevertheless, only a small fraction, in the micro-Joule range, was used during this work.

First two weeks the work was focused in two jobs: getting familiar familiar with the compressor system and preparation of some tools for the spatial chirp characterization. The job with the compressor implies learning how to align and optimize the dispersion introduced by a grating pair in a two pass configuration in order to compensate the dispersion presented in the pulse train. Both gratings are mounted on rotation stages and one of them over a translation stage to adjust the distance between the gratings. Rotation and separation are used to adjust dynamically the dispersion introduced in the compression system. The alignment quality was evaluated with a single shot autocorrelator from the company Avestas. Pulses as short as 29 femtosecods were measured. Some optical elements, detectors and a motorized unit has been prepared for spatial chirp measurements. The spatial chirp characterization method proposed by Stephane Petit uses of narrow band pass filters, a motorized filter wheel and a position detector/CCD camera to measure the beam pointing for different wavelengths and, hence, spatial chirp.

During the next two weeks the main work load was focused in the study of spatial chirp introduced by a missalignment in the parallelism of both gratings. Spatial chirp has been monitored/corrected by using the following methods:

1. A single shot autocorrelator was used to measure the pulse duration dependence with the gratings alignment. The minimum pulse duration is obtained when the spatial chirp is minimized.

2. A CCD from Thorlabs is used to study the beam spot position in the focal plane when the beam is spectrally filtered inside the compressor to remove the central wavelengths of the pulse. The spectral wings beam spot overlaps when spatial chirp is minimized.

3. The CCD is also used to gather the spot position in the focal plane when the beam is spectrally filtered after the compressor by using three narrow-wavelength bandpass filters (3 nm wide) with central wavelengths of 780, 808 and 830 nm. As the previous method, the beam spots must overlap when spatial chirp is removed.

4. Spectral distribution in the beam profile after the compressor. This is achieved by horizontally sweeping the transverse beam profile with a spectrometer and studying how the central wavelength behaves. Spatial chirp leads to a central wavelength wander.

All the methods allow us to correct the spatial chirp by following an iterative process where we measure the spatial chirp and then adjust the rotation of the second grating and the retro-reflector mirror to measuring, adjustment and measuring again.

We work on the automation of a spatial chirp diagnose system using the band pass filters, the CCD camera and the motorized filter wheel. We explore several approaches and found a huge amount of problems. Further studies must be carried to improve the usability/simplicity of the system.

b) The following resumes the work carried out by Oscar Varela Baquero during his stay at the Centre Lasers Intenses et Application (CELIA) in Bordeaux. During this period of time (4 weeks), two tasks have been proposed.

1) The first one involved to build a Treacy grating pulse compressor for kHz laser beam (25 Femtoseconds) and learn how to align and optimize this kind of femtosecond pulse compressor.

2) The second one was to work with different systems to study and characterize the spatial chirp induced by this kind of pulse compressor due to a non parallelism of both gratings (i.e. spatial chirp due to angular dispersion).

A Treacy compressor was built from the beginning, observing and learning all the troubles and difficulties that can appear during its alignment and optimization. Also, in addition to the use of an autocorrelator, two complementary schemes were implemented in order to to do a fine adjustment of the spatial chirp induced by the non parallelism of both gratings of the compressor;

1) on the one hand a commercial imaging spectrometer (SpectraPro 300i) was used. Focusing the beam into the imaging spectrometer we can measure the spectral components for each spatial point of the beam profile along the horizontal axis (the axis in which we induce the spatial chirp). If some spatial chirp exists due to angular dispersion in the horizontal axis we should observe a slope different from 0 in the image of the first order of the spectrometer, which means that, the different wavelengths focus in different spatial positions along the horizontal axis.

2) on the other hand the beam was focused into a CCD camera or/and a beam positioned using two narrow spectral band filters (3 nm of bandpass width) centered in 780 and 820 nm. If we filtered the beam by using these spectral filters we can observe how different is the spatial position along the horizontal axis of the spot generated by each spectral components that pass through the filters when exist spatial chirp.

The objective of this task was to study and compare both schemes and conclude if we can use one of these methods to adjust the alignment of the parallelism of the gratings without the use of the autocorretor.

The results show that both methods studied are enough to find very good results very easy and very quick but at the end an autocorrelator is needed to find the shortest pulse that you can achieve. Pulses shorter that 25 femtosecond were achieved, obtaining the same results that in the others compressors in use in the laboratory.

vi) CLPU – CLF

Sending Institution: Centro de Laseres Pulsados Ultracortos Ultraintensos, Salamanca, Spain

Hosting Institution: Central Laser Facility, Rutherford Appleton Laboratory, STFC, UK

Duration: 4 weeks

Participating staff: Javier Santamaría, José-Manuel Álvarez

Objectives of the exchange: The objective of this exchange is to acquire experience on the implementation and operation of radiation safety codes in order to control the ionising radiation produced by high intensity laser matter interactions. In particular we want to learn about the radiation monitoring system for the environment and safety implemented at the Central Laser Facility. We intend to achieve these objectives by spending four weeks in the Central Laser Facility, at the time that an experimental campaign with the Vulcan (or Astra) Laser is taking place. This exchange is focused on the radiological protection aspects but it will also help us to acquire hand-on experience on the detection of ionizing radiation produced by intense lasers.

Achievements: As a result of to this Staff Exchange we have accomplished the following results:

- We have acquired experience on the implementation and operation of the safety system implemented at the Central Laser Facility. This experience has been crucial to elaborate a proposal for the security system that should be implemented at the CLPU.
- We have been involved in two different experiments: at the Target Area of the Astra-Gemini Facility and at the Target Area of VULCAN Facility. This has provided us first hand experience with the safety procedure implemented in both facilities, which are quite different from the point of view of the user, although both cases fulfil the high standards required at the CLF. Even the international standard IEC 61508 is not mandatory for a

safety system, it has been assumed at the CLF and is being under considerations for the safety system proposed at the CLPU.

- We have acquired hand-on experience on the detection of ionizing radiation produced by intense lasers. Besides knowing the network of detectors implemented at the Astra-Gemini facility and the web-based program for displaying the scintillator trace (the so-called eCAT2), we have also used the radioprotection laboratory and its instrumentation. Thus, for instance, during both experimental campaigns we have used Thermoluminescent Dosimeters (TLDs) in order to monitoring the dose produced by the radiation field of photons. Those TLDs have been read by the instrumentation available at the radioprotection laboratory at the host institution.
- In addition to the TLDs measurements, we have simultaneously performed a campaign of measurements with Electronic Personal Dosimeters (EPDs). A total of 10 EPDs from Thermo Scientific, were brought to CLF in order to study their response to the radiation field of photons generated at the Target Area during the experiments. Although there has not been any response of the EPDs (despite variation of distances and angles to the source of radiation) in none of the two experiments, our host (Dr. Rob Clarke) agrees with us that it worth to perform another campaign of measurements at CLF with those devices.
- Last, but not least, this Staff Exchange is a start point for a long-term collaboration between CLF and CLPU related with a best practice concerning radioprotection issues in a Laser Facility. In fact, we are considering to bring other detectors to the CLF in order to study their response before their incorporation to the network of detector that should control the dosimetry at the Target Area of the CLPU facility.

In summary, the main objective of this Staff Exchange, focused in technical know-how and best practices concerning radioprotection issues, has been successfully accomplished. This call has been a valuable opportunity to acquire experience on the operation of radiation safety in intense laser facilities.

vii) CLPU – LULI

Sending Institution: Centro de Laseres Pulsados Ultracortos Ultraintensos, Salamanca, Spain

Hosting Institution: Laboratoire pour l’Utilisation des Lasers Intenses, CNRS, Palaiseau, France

Duration: 3 weeks

Participating staff: Isabel Gallardo González

Objectives of the exchange: The objective of this exchange is to acquire useful knowledge and experience on the diagnostics of high-intensity large-aperture lasers and the adaptive optics systems for the enhancement of their beam focusability.

Achievements: The Staff Exchange Program experience has been an immersion on the needs and goals for the technical management of a high-power laser facility as LULI, which counts with a long trajectory in giving service to many users.

This participation showed how the arrangement of a laser facility lies in two dimensions. At one part, all the technical and scientific knowledge and practice required for handing and improving the laser system itself. At the other, the elaboration of a structure able to give laser service to the users community in a reliable, efficient and safety way.

Attending to the first one, during the four weeks daily technical support and maintenance at ELFIE has been followed. Daily procedures for laser tune-up and supervision of different diagnostic points along the complex laser chain revealed crucial for a convenient performance of the laser and to preserve the system on any fatal damage. Alignment system and diagnostics units were developed at ELFIE in the most appropriate way regarding the laser inquires. Adaptive optics systems are chosen in terms of the particular needs of the systems and their application, varied documentation has been provided. The technical support included participation on conflicts resolution and technical inquires arisen during the campaign. At the end of the stay the maintenance week gave the chance of sharing the actions that periodically are made on the system to keep its quality and improve its performance. Training in optical components design software as ZEMAX and in development of testing bench to check the optics purchased have also taken part.

On the other side, the general sight of the experience allowed remarking the importance of the arrangement of the different teams needed for the operation, mainly focused on the laser, software, synchronization, supplies, experimental area, target issues and research lines. Such a multidisciplinary work also yields to the need of the management of a big amount of documentation involving the laser system, which must be accessible and understandable for the progress of the facility. An overview of the many other surrounding installations also took place, principally high voltage, vacuum, clean rooms, cooling systems and air conditioning installations. Target area and beam line configurations were showed as the last step on the experiment support. It has been stressed the security measures, safety training, radioprotection issues and risk analysis involved in the manipulation of any part of the facility. The rest of the LULI systems and projects were also introduced (LULI2000, LUCIA, APOLLON) emphasizing also their technical and diagnostics characteristics.

The global practice has approach the background of the technical team role in an experienced high-power laser as ELFIE. This knowledge has a great value for the settlement of CLPU new facility and will hopefully open a path of collaboration for the exchange of ideas and solutions useful for both facilities.

viii) ILC – VULRC

Sending Institution: International Laser Centre, Bratislava, Slovakia

Hosting Institution: Laser Research Center, Vilnius University, Vilnius, Lithuania

Duration: 1 week

Participating staff: Dusan Chorvat

Objectives of the exchange: The proposed project for scientific staff exchange is focused on the strengthening of collaboration and knowledge sharing in the field of 2-photon photopolymerization (2PP) and related micromachining techniques based on pulsed laser radiation. Main objective is to set common standards for technology and good laboratory practice in the 2PP techniques in the newly developed setups at the laboratories of ILC in Bratislava according to the knowledge developed within the previous phases of Laserlab Europe project at VULRC in Vilnius.

Achievements: My stay included visits to following laboratories: former and newly established installations of Laser nanophotonics group, Training laboratory of quantum electronics, Training laboratory of laser technology and optical materials, and briefly some other laboratories of the VULRC open for Access programme in Laserlab Europe. The knowledge sharing in the field of 2-photon photopolymerization and related micromachining techniques was based on personal discussions and joint experiments with the individual members of the Laser nanophotonics group, starting with the leader prof. Roaldas Gadonas (general concepts and instrument development), Dr. Mangirdas Malinauskas (nanophotonics and details of experimental workstation design) and Dr. Vytautas Purlys (software and programming issues). On the other hand, during May 28, 2014 I have presented a talk "Laser micro/nano-fabrication at ILC" describing the state of these technologies at my mother institute - International Laser Centre in Bratislava, Slovakia - for the members of VULRC.

On top to purely technical discussions, fruitful scientific information exchange was held also with prof. A.Piskarskas, former director of QED and VULRC, and teams of prof. R.Gadonas (Laser nanophotonics group) and prof. V.Sirutkaitis (leader of Optics characterization group and director of VULRC). These groups are our partners in the Joint research activity Bioptichal within the project Laserlab Europe III. Possible areas of cooperation between

VULRC and ILC in developing new technologies for material processing using short-pulsed laser sources within the new project proposal "Laserlab Europe IV" were also discussed.

In addition to visits directly at VULRC, during the stay I visited the R&D labs of the distinguished industrial partners of VULRC: companies Light Conversion and Femtika. The information gathered in relation to VULRC research program was very informative an extremely important for future development of closer working contact of ILC with perspective industrial partners.

In summary, the visit was highly successful and main objective of my stay - to improve understanding and set a common standards for technology and good laboratory practice in the 2PP techniques- were fully achieved. The visit will help to establish the optimal program for newly installed experimental setups for 2PP in my home laboratory at ILC in Bratislava, according to the knowledge developed by VULRC within the previous phases of Laserlab Europe project. The added value of the visit was development of closer scientific and personal contacts between ILC and VULRC.

ix) LP3 – LLC

Sending Institution: Laboratoire Lasers, Plasmas et Procédés Photoniques, CNRS, Marseille, France

Hosting Institution: Lund Laser Centre, Lunds Universitet, Lund, Sweden

Duration: 3 days

Participating staff: Vadim Tcheremiskine

Objectives of the exchange: The LP3 lab is involved in a project of X-rays generation by intense (I>10E16 W.cm-2) femtosecond laser, provided by the multi-TW ASUR facility. This facility can provide simultaneously five different beam lines with power level up to 20 TW per pulse, including a beam line with unique performances (10 TW, 100 Hz). The maintenance of such a facility, the management of the multi-user aspect and the security (security associated with laser and laser generated X-rays) are a prerequisite to the success of the associated projects.

The Lund High-Power Laser facility allows access to a multi-TW with peak power (40 TW) comparable to one of the ASUR beam line (20 TW). The Ultrafast X-rays science research group have years of experience in the management of multi TW laser sources and experiments involving peak intensities higher than 10E16/10E17 W.cm-2). Their experience will be very profitable to the LP3 which lacks of experience in this domain.

The staff members to be exchanged (2 people) are supposed not only to maintain and manage the multi-TW facility on a day -to-day basis, but also to be active parts of the team involved in projects associated with high laser intensities. This is why this exchange will be mainly focused on the management of a multi-TW facility (maintenance, security and multi-users management) and the safe development of experiments involving high (relativistic) laser intensities.

Achievements: Fruitful discussions have been performed. These discussions concern the techniques of generation of ultra-high intensity femtosecond laser pulses, their interaction with matter and applications to generation of ultra-short X-ray pulses, as well as applications of femtosecond X-ray pulses to study ultra-fast physico-chemical processes.

Helpful recommendations on the improvement of the ASUR laser facility (LP3) for end-user applications have been elaborated.

x) LULI – CLF

Sending Institution: Laboratoire pour l'Utilisation des Lasers Intenses, CNRS, Palaiseau, France

Hosting Institution: Central Laser Facility, Rutherford Appleton Laboratory, STFC, UK

Duration: 3 weeks

Participating staff: Loic Meignien

Objectives of the exchange: To acquire knowledge and experience in development of state of the art temporal shaping systems for ns long pulses; amplification of these pulses in diode-pumped regenerative and fibre amplifiers; identification of potential joint projects in the development of shaped long pulse systems.

Achievements: This exchange enabled a continuation of the work started in the earlier exchange between the two laboratories. The main purpose of this exchange was to study and exchange ideas on seed sources commonly used in glass laser chains with a focus on nanosecond temporally tailored laser pulses, (SLP).

We reviewed and discussed many subjects relating to the two facilities commonalities both in technical characteristics of the systems and the procedures to operate them.

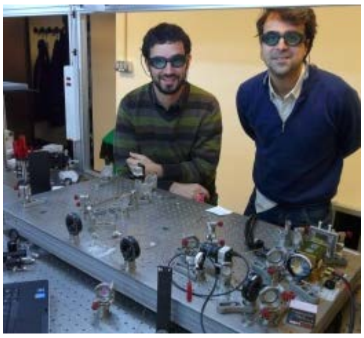
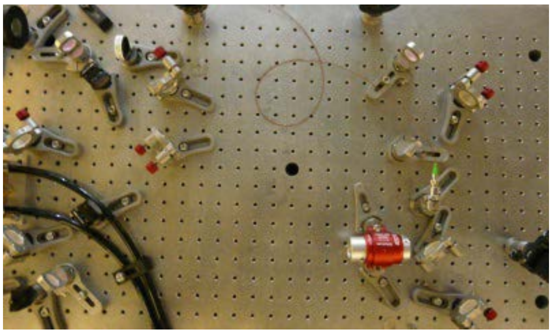
We had a deep and detailed exchange on Front-end (seed) laser systems for the glass laser chains, both on long pulses (nanosecond) and short pulses (picosecond), OPCPA systems and operating long pulse systems in Vulcan as well as in LULI2000 laser.

As part of the exchange we visited the Orion laser facility and had the opportunity to discuss in detail their experiences with long pulse laser seeds. We discussed their design, as well as the fact that they can operate their SLP systems in CW mode to align the facility. During the Orion visit we discussed new possible designs for such systems as well as a detailed visit to the entire laser facility.

Having the main objective of this exchange in line, we have:

1) Tested equipment existing in the CLF which was not available at LULI, some of this instruments were partially known to the CLF, some were novelties, that had not been tried before, among them:
    a. A double BBO Pockels cell (PC) with a low impedance and a theoretical rise/fall time of 1 ns. We measured the rise/fall times and found them to be substantially higher and that noise contaminated the rise/fall time of the PC.
    b. A CW pumped Nd:YLF laser head. We observed and measured several unique characteristics of this laser head:
        i. An astigmatic thermal lens on both polarizations;
        ii. A birefringence of the beam passing in the laser head;
        iii. A pump wavelength at approximately 900 nm.
        iv. The possibility of amplifying light at 1047 nm and 1053 nm.
        v. We have also measured the small signal gain of this rod at 1053 nm on both horizontal and vertical polarizations.
2) We built a CW laser which is the main step in building a SLP. The aim was to eliminate counter propagating beam superposition in the gain crystal, which results in temporal deformations that are difficult to compensate and that had been observed on both facilities. In order to do this instead of a linear cavity we used a ring cavity. Several different cavity configurations were tried to study the geometrical stability of the cavity:
    a. A single waist cavity which due to the long cavity length presented a mode too big in the crystal,
    b. A double waist cavity which proved to be a stable cavity.
    c. We tested also several cylindrical lenses in order to compensate for the astigmatic thermal lens introduced by the CW pumped Nd:YLF laser head.

At the end of this short stay we had a ring laser CW cavity with an output power of which is between 1 and 1.5W at each one of the 4 outputs.

xi) CLF – LULI

Sending Institution: Central Laser Facility, Rutherford Appleton Laboratory, STFC, UK

Hosting Institution: Laboratoire pour l'Utilisation des Lasers Intenses, CNRS, Palaiseau, France

Duration: 3 weeks

Participating staff: Pedro Oliveira

Objectives of the exchange: To acquire knowledge and experience in development of state of the art temporal shaping systems for ns long pulses; amplification of these pulses in diode-pumped regenerative and fibre amplifiers; identification of potential joint projects in the development of shaped long pulse systems.

Achievements: This exchange as initially proposed was to study nanosecond temporally shaped pulses, commonly known as shaped long pulses (SLP) and the requirements to inject them into large aperture Nd:glass laser chains. Both labs have some experience of this matter and the purpose was to interchange that experience and to be able to build upon that to design and construct new systems. In particular the traditional design of these systems includes a nJ, ns temporally shaped pulse normally given by a fibre system, and second a regenerative amplifier to take this pulses up to the mJ energy level.

Several objectives were achieved:

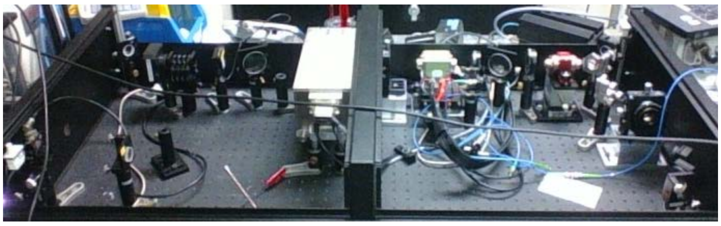
1. The sharing of technical information, about long pulses, both the fibre seed creation and regenerative amplifier design. This included a trip to an important supplier, photline which supplies the EOM modulators used by both laboratories.
2. A better understanding of the systems and components in SLP and its alternatives. Including:
   a) A better understanding of the pulsed diode-pumped Nd:YLF head LULI uses, both the cut of the rod, the existence of birefringence effects and the gain possibilities it had.
   b) A thorough analysis of pulsed laser diodes, viewing them as alternative sources for CW fiber lasers/fibre laser amplifiers.
3. The design and construction of a SLP system. More specifically a regenerative amplifier with the following characteristics:
   a) a bifocal ring cavity;
   b) 17 ns roundtrip time;
   c) 15 mJ output pulse energy;

The pulsed YLF head used by LULI allows a small signal gain up to 3.5 and an energy output of up to 40 mJ, it can amplify 1053 nm light both on the horizontal and vertical polarizations. This is very interesting for a ring cavity design where light may go through the amplification rod both with horizontal and vertical polarizations. This eliminates the need for a wave-plate in the system reducing losses. It presents however a birefringence which does not allow the cavity to be fully stable.

The possibility of having a pulsed diode source as the seed source for a SLP is a very interesting one, in reality it can provide us with a factor of 10 increase in the peak power and a factor of 9 reduction of price.

We studied this possibility and arrived at several interesting technical results. First the diode lasers present a significant wavelength shift from the CW wavelength, which did not allow us to use the envisioned diode laser. In addition to the frequency shift, it also presents a spectral enlargement which even if it might be inconvenient for some experiments might be interesting for high energy shots and avoidance of stimulated Brillion scattering.

The SLP laser system that was built in LULI during this short stay is now in operation for the users of the facility.



xii) UL – ILC

Sending Institution: Laser Centre of the University of Latvia, Riga, Latvia

Hosting Institution: International Laser Centre, Bratislava, Slovakia

Duration: 3 weeks

Participating staff: Inesa Ferulova

Objectives of the exchange: The proposed project for scientific staff exchange is focused on the mastering of skills for effective data acquirement and processing in the field of multidimodal optical imaging. Main objectives of the exchange is to obtain practical knowledge in the experimental techniques of laser scanning microscopy and fluorescence lifetime spectroscopy and imaging (FLIM), as well as to gain experience in data analysis and interpretation of multimodal bioimaging datasets.

The added value of the proposed project is development of closer scientific contacts between ILC and UL, based on research and development of new experimental approaches for multimodal imaging and data analysis under the framework of joint research activity (JRA) Bioptichal.

Achievements: During my stay at the International Laser Center (ILC) in Bratislava, a method and a protocol for parallel imaging of tissue Fluorescence-lifetime imaging microscopy (FLIM) and photobleaching rates (PBR) were developed. Measurements were done on cells and skin (in-vivo and in-vitro) in the visible spectral range, combining the photobleaching method and fluorescence lifetime on confocal microscope. The method for fluorescence lifetime measurements during photobleaching was develop based on the results obtained in Riga (lifetime changes during photobleaching of in-vivo human skin) and the results obtained in Bratislava (autofluorescence lifetime of FAD and NADH).

The measurements of cell autofluorescence were focused on FAD, NADH and lipopigments. The results show how lifetime changes for specific fluorophores during photobleaching. This experiment allows to understand which fluorophores are more influenced by photobleaching.

The same method was applied for measurements on human skin. The results were analyzed together with the ILC team using the programs SPCImag , FAST, ZEN.

The obtained results of cell autofluorescence lifetime changes were compared to the results of lifetime changes during photobleaching of human skin in order to better understand what fluorophores could be influenced by photobleaching in human skin. At the same time confocal microscope was used to obtain autofluorescence spectrum. Spectral unmixing was then done to understand what fluorophores were under excitation.

Conclusions:

1. A method and a protocol for lifetime measurements during photobleaching were developed.

2. Results of autofluorescence lifetime of FAD, NADH, lipopigments during photobleaching of cells and skin were acquired and analyzed.

3. Ideas for further measurements and future collaboration were discussed.

xiii) ICFO – POLIMI-CUSBO

Sending Institution: The Institute of Photonic Sciences, Barcelona, Spain

Hosting Institution: Centre for Ultrafast Science and Biomedical Optics, Politecnico di Milano, Dipartimento di Fisica, Milan, Italy

Duration: 3 days

Participating staff: Marco Pagliazzi

Objectives of the exchange: The key goal is to align the best laboratory practices and procedures of the two laboratories in the accurate characterisation of reference material and in the performance assessment of diffuse optics instrumentation for biomedical applications.

An impellent need, which is often stressed by authoritative institutions such as the National Institute of Health (NIH), is the quantitative assessment of new instruments for translation to clinics. Given its wealth of unique workstation with top-class performances, LaserLabEurope has often taken a leading role in this direction and is a continuous reference in the field. The proposed staff exchange has the aims to consolidate the culture of rigorous quality assessment of instrument among staff personnel and researchers, as well as to share best practices on phantom construction and characterisation. A twin proposal is being submitted by POLIMI-CUSBO with complementary aims.

The specific goals will be:

- compare recipes and step-by-step fabrications of tissue simulating phantoms. This is often a tricky task since it depends on long-term expertise and adaptation to the diverse needs

- compare approaches and practical implementations on accurate phantom characterisation, by adopting different strategies depending on the type of phantom (e.g., solid, dynamic, inhomogeneous)

- learn and practice on EU based Protocols for performance assessment of diffuse optical instruments

Achievements: The key goal was to align the best laboratory practices and procedures of the two laboratories in the accurate characterization of reference material and in the performance assessment of diffuse optics instrumentation for biomedical applications. Marco Pagliazzi, a PhD student, working at ICFO on the preparation of new approaches for phantom construction for diffuse correlation spectroscopy visited POLIMI to test and compare the new phantom recipes that he has devices as a motility standard.

Main achievement of this visit was the collection of broadband spectra for testing the phantom recipe as well as the testing the feasibility of introducing the standard diffuse correlation spectroscopy laser in measurements of time resolved spectroscopy by CUSBO.

The visit was successful and further work was carried out remotely. This visit was co-funded by other sources.

xiv) POLIMI-CUSBO – ICFO

Sending Institution: Centre for Ultrafast Science and Biomedical Optics, Politecnico di Milano, Dipartimento di Fisica, Milan, Italy

Hosting Institution: The Institute of Photonic Sciences, Barcelona, Spain

Duration: 1 week

Participating staff: Antonio Pifferi, Davide Contini

Objectives of the exchange: The key goal is to align the best laboratory practices and procedures of the two laboratories in the accurate characterisation of reference material and in the performance assessment of diffuse optics instrumentation for biomedical applications.

An impellent need, which is often stressed by authoritative institutions such as the National Institute of Health (NIH), is the quantitative assessment of new instruments for translation to clinics. Given its wealth of unique workstation with top-class performances, LaserLabEurope has often taken a leading role in this direction and is a continuous reference in the field. The proposed staff exchange has the aims to consolidate the culture of rigorous quality assessment of instrument among staff personnel and researchers, as well as to share best practices on phantom construction and characterisation. A twin proposal is being submitted by ICFO with complementary aims.The specific goals will be:

- training on practical use of diverse clinical instruments so to understand criticalities and specific needs

- use of dynamic phantoms for validation and calibration of diffuse correlation spectroscopy (DCS)

- get hands-on expertise on cross-comparison of instruments based on different approaches (e.g. space-domain, frequency-domain, time-domain).

Achievements: The key goal of the exchange was to to align operational capacity and standard procedures of the two laboratories in the use and performance assessment of diffuse optics instrumentation for biomedical applications. In particular, 2 instruments/techniques were considered, namely Time-Resolved Diffuse Optical Spectroscopy (TRS) and Diffuse Correlation Spectroscopy (DCS). The joint activity was based on:

- best practices in defininig the optimal operating conditions in terms of signal level and temporal resolution.

- comparison of software structure aimed at achieving self-adapting control of the operation

- performance assessment on phantom measurements

- standardization of fitting procedures.

The key achievements of the exchange are:

1) sharing of best laboratory practices among the two teams;

2) enforcing the common attitude towards standardization and performance assessment of instruments.

xv) GSI – CLF

Sending Institution: Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany

Hosting Institution: Central Laser Facility, Rutherford Appleton Laboratory, STFC, UK

Duration: 2 days

Participating staff: Christian Brabetz, Udo Eisenbarth

Objectives of the exchange: Start of collaborative work on development on adaptive optics system. Detailed exchange on the work that each laboratory already performed. Inspection of hardware. On site visit to define the requirements for further development.

Achievements: Goal was an exchange of knowledge on adaptive optics of both facilities and starting a collaboration thereon. This was fully achieved. In detail:

- Measurement of the wavefront: Both facilities explained their home made systems. Comparison to commercial available systems were also explained and discussed.

- Correction of the wavefront: In terms of static compensation and live thermal aberration. We discussed several new implementations and material properties. Explained and showed our experience we gathered with live thermal aberration correction.

- Visit of the AO laboratory at CLF and the Vulcan and Astra laser facilities.

- Collaboration: Starting work on a full closed loop AO system. CLF is experienced in deformbale mirror manufacturing. PHELIX has gathered detailed experience in measuring and analysing the wavefront which controls then the mirror. Hardware exchange will then follow.

xvi) CLPU – CELIA

Sending Institution: Centro de Laseres Pulsados Ultracortos Ultraintensos, Salamanca, Spain

Hosting Institution: Centre Lasers Intenses et Applications, University of Bordeaux, CNRS, Bordeaux, France

Duration: 4 weeks

Participating staff: Enrique Garcia

Objectives of the exchange: The objective of this exchange is to acquire hands-on experience on the study and characterization of B-integral compensation by nonlinear crystal for high repetition rate CPA lasers.

Achievements: Enrique García has realized his stance under the supervision of Stephane Petit from CELIA. During the exchange at CELIA laboratories, Enrique Garcia spent most of the time at Solstice laser chain, a 100 kHz, 500 fs close to the mJ energy, nevertheless he only worked with energies on the range of 50 µJ. He gained experience with the laser and learn daily maintenance task like system start-up and slightly optimization of the energy/mode of one of the amplifier rods. He also participated on other technical maintenance like the exchange of a chiller plus the piping for a continuous wave pump laser diode, the study of the stability of the optical tables, or the use of some characterization equipment like precision spectrometer, CCD cameras, autocorrelators, ...

The objective of this exchange was to acquire hands-on experience on the study and characterization of B-integral compensation by non-linear crystal for high repetition rate CPA lasers.

The first part of the stance was focused on the implementation of a spectral interferometer to perform the measurement of the B-integral. An energy-balanced Mach Zehnder-like interferometer was mounted and aligned. The interferometric spectrograph allowed us to measure the B-integral acquired on one of the interferometer arms by applying a Fourier analysis to the signal measured with a precision spectrometer. Number and contrast of the fringes presented in the spectrograph was optimized to obtain reliable values.

The second part of the stance objective require to study the technical requirements in order to use the cascading non-linear effect to inject a controlled negative non-linear phase shift into the pulse to compensate the B-integral. BBO and BIBO non-linear crystals were used to introduce the phase shift in one of the arms of the spectrometer and hence, being able to measure the non-linear phase shift using the unperturbed arm as reference. Preliminary results showed a slight shift in the phase introduced by the non-linear crystal, but further optimization is needed to improve the amount of phase shift induced.

In addition to this work, he was included in the technical staff, having the opportunity to participate in technical/maintenance meetings and discussions, winning experience on such field.

xvii) CLPU- LLC

Sending Institution: Centro de Laseres Pulsados Ultracortos Ultraintensos, Salamanca, Spain

Hosting Institution: Lund Laser Centre, Lunds Universitet, Lund, Sweden

Duration: 2 weeks

Participating staff: Irene Hernandez

Objectives of the exchange: The objective of this exchange is to acquire hands-on experience, and pool know-how in both running and improving CPA laser systems.

Achievements: During her stay for two weeks at the Lund Laser Centre, Irene Hernández has been supervised by Dr. Anders Persson. She has followed the upgrade of LLC 40-TW system, a 10 Hz 35 fs, 40 TW laser, as well as the daily monitoring and the maintenance tasks of the system.

1. She has followed the alignment of the multipass amplifier after the exchange of the Ti:Saphire crystal, performing tasks such as:
    - The alignment of IR mirrors
    - The adjustment of the cryogenic system to the correct height for the set-up.
    - The sketch of the imaging system for the pump lasers
2. In addition, other maintenance task like:
    - The alignment of the spatial filter located before the main amplifier.
3. She had followed some improvements in the system like:
    - The exchange of mounts for a beam splitter located at the output of the preamplifier, in order to being able of choosing between a mirror or a beam splitter, depending on the user's necessity, without changes in the alignment.
    - The positioning of a camera for the alignment with the help of an iris.

She learned how to proceed in these cases, the resolution of troubles that can appear and how to solve it.

2.2 Task 2b) Joint Experiments

Joint Experiments are jointly proposed and conducted by scientists from one or more partners involved in the Laserlab-Europe Transnational Access Programme. The objective is to reinforce the scientific collaboration between these Laserlab-Europe partners and to gather their expertise in order to carry out very ambitious research studies at the forefront of their scientific domain. If necessary, the experiment may also be carried out at several laboratories with complementary contributions. Applications for Joint Experiments are subject to scientific evaluation by an external Selection Panel with excellence as the main criterion. The infrastructure hosting a Joint Experiment will provide free access to its installation without charging any User Fee. Proposals for such experiments are possible at any time.

During the lifetime of the project, 15 proposals for “Joint experiments” were received and evaluated by the Selection Panel. Following acceptance, 33 scientists from 8 labs were involved in 10 experiments. The following joint experiments were performed:

i) CNRS/CEA – LLC

Sending Institution: Laboratoire pour l’Utilisation des Lasers Intenses, CNRS, Palaiseau, France, and CEA-Saclay - SPAM, Saclay, France

Hosting Institution: Lund Laser Centre, Lunds Universitet, Lund, Sweden

Duration: 10 days

Participating staff: Brigitte Cros, Frédéric Desforges, Sandrine Dobosz Dufrénoy, Jinchuan Ju

Objectives of the exchange: The main objective of this project is to measure in detail the characteristics of electron bunches and the associated X-ray betatron radiation produced in long plasmas, to achieve a better understanding of the mechanisms which control the X-ray spectrum. The use of capillary tubes as waveguides allows to generate electron bunches in a large range of plasma densities and lengths and the effect of these parameters will be studied. The spectra of accelerated electrons and of the X-ray radiation produced by betatron oscillations will be measured. A spherically bent crystal spectrometer will be used to measure X-ray spectra in the 1-10 keV range and image the X-ray distribution. As the X-ray and electron bunch parameters are closely linked a better description of both electron acceleration and X-ray emission will be obtained through the comparison with PIC simulations.

Achievements: The experimental campaign worked very well. Active stabilization of the laser pointing was used and laser parameters were recorded on each shot Thanks to the high laser beam pointing stability of the Lund TW laser long data series of laser wakefield acceleration in gas filled dielectric capillaries could be recorded, and the stability of the electron beams investigated. These beams were found to be more stable in charge and pointing than the corresponding beams of electrons accelerated in a gas jet. Electron beams with an average charge of 43 pC and a standard deviation of 14% were generated. The fluctuations in charge were found to be partly correlated to fluctuations in laser pulse energy. Gas density fluctuations, between different laser shots, were suspected to be a more important source of instability. The pointing scatter of the electron beams were measured to be as low as 0.8 mrad (rms).

Reproducibility of electron beams from laser wakefield acceleration in capillary tubes, Desforges F.G. et al., Nuclear Instruments & Methods in Physics Research A 740, 54, 2014, http://dx.doi.org/10.1016/j.nima.2013.10.062

ii) ILC – LENS

Sending Institution: International Laser Centre, Bratislava, Slovakia

Hosting Institution: Laboratorio Europeo di Spettroscopie Non Lineari, Sesto Fiorentino (Florence), Italy

Duration: 3 days

Participating staff: Dusan Chorvat, Martin Uherek

Objectives of the exchange: The project has ambition to contribute to understanding of the mechanisms of changes in collagen reorganization in aorta wall accompanying development of cardiovascular diseases, using nonlinear microscopy imaging - in particular second harmonic generation (SHG). The organization of collagen fibers studied by SHG imaging has the potential of being used as a probe for determining the risk factor associated with a cardiovascular disease, and will significantly enhance results obtained by our group so far using standard microscopy techniques.

Main objectives of the proposed research are:

1. Measurement of spatially and spectrally resolved signal from collagen in rat aorta using pulsed femtosecond laser excitation,

2. Research of the potential of simultaneous SHG and autofluorescence / FLIM (fluorescence lifetime) imaging of unstained aorta for diagnostics of cardiovascular diseases,

3. Investigation of structural (re)organization of collagen in rat aorta by computational analysis of SHG images.

Achievements: In this study we investigated rat aorta samples (fixed in formaldehyde) from three different animals using second harmonic generation (SHG) and fluorescence imaging. We proved feasibility of quasi-simultaneous measurement of the spatial distribution of collagen related to SHG signal, and NADH and flavin molecules manifested by cellular autofluorescence. The data gathered within this study significantly advanced our understanding of the mechanisms of changes in collagen organization in aorta wall, accompanying development of cardiovascular diseases. The visit also allowed us to gain knowledge leading us to successful implementation of a new imaging modality (forward SHG) in the Laboratory of laser microscopy at ILC, Bratislava within the frames of JRA Bioptichal.

Using the advanced setup for nonlinear microscopy imaging at LENS we were able to image structural details of three different samples of aortas i) from control animals - Wistar rats, ii) rats fed with cholesterol-rich diet, and iii) rats with diabetes induced by streptozotocin. We imaged the rat aorta wall by second harmonic (SHG) imaging using 840nm excitation by Ti:Sa femtosecond laser (Chameleon, Coherent, USA). SHG images from all samples were acquired as a 3D data stack at three different locations of aorta, using two different objectives (20x / 40x). Overall, 18 (3x6) three-dimensional datasets were acquired, in addition to several high-resolution 2D images. In comparison to the preliminary data obtained previously at ILC using ytterbium 1038nm laser, the images gathered during the PCS stay show higher contrast and resolution, as well as better deep-tissue transmission. For control samples we used also the fluorescence detector and setup for time-correlated single photon counting to image spatial distribution of autofluorescence and autofluorescence lifetimes in NADH and flavin regions (excited by 740nm and 840nm, respectively). The experimental data were numerically and statistically analyzed to characterize spatial frequencies in different sample types, allowing to more precisely quantify the collagen fiber arrangement.

The results of the study were presented at Laser Physics Workshop, July 2012, Calgary in the form of a lecture "High-resolution second-harmonic generation imaging of rat aorta" and at Mikroskopie 2013 - annual conference of Czecho-Slovak Microscopy Society, Lednice, Czech Republic as a poster presentation: "Advanced optical imaging of aorta".

iii) LOA – GSI

Sending Institution: Laboratoire d'Optique Appliquée, Palaiseau, France

Hosting Institution: Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany

Duration: 8 days

Participating staff: Eduardo Oliva, Philippe Zeitoun, Lu Li

Objectives of the exchange: The goal of this experiment is to measure the energy extracted when seeding plasma based amplifiers of soft X-ray radiation. A more-than-linear increase of energy with plasma width has been proposed from hydrodynamic simulations, explained with the role of 2D hydrodynamical effects. Since these optimal amplifiers (short and wide) are on the opposite point of state of the art amplifiers (long and narrow) it is necessary to study experimentally this correlation. In this experiment we plan to measure the output energy of different sized amplifiers, seeded with another smaller plasma to overcome self-emission. The total output energy will be measured to study the correlation between plasma width and extracted energy.

Achievements: An improvement of the brilliance of the Ni-like Mo X-Ray laser by nearly two orders of magnitude was achieved.

iv) LOA – MBI

Sending Institution: Laboratoire d'Optique Appliquée, Palaiseau, France

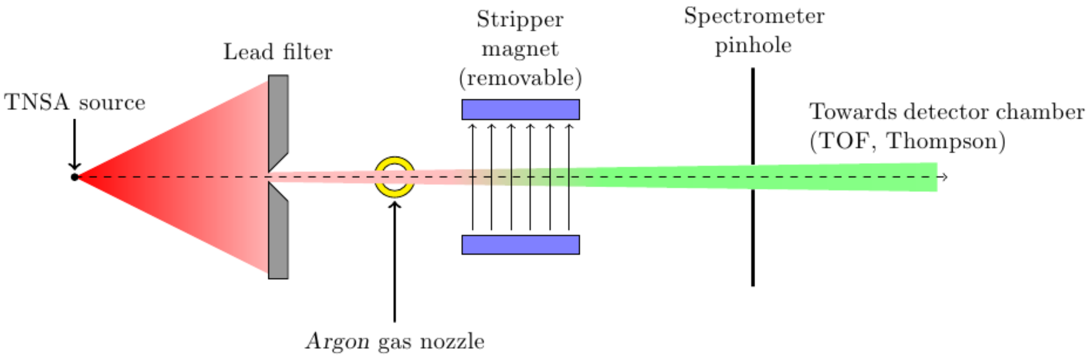
Hosting Institution: Max Born Institute for Nonlinear Optics and Short-Pulse Spectroscopy, Berlin, Germany

Duration: 4 weeks

Participating staff: Victor Malka, Alessandro Flacco, Florian Mollica, Benjamin Vauzour, Giulia Folpini, Gabriele Birindelli, Luca Antonelli

Objectives of the exchange: The creation of neutral or negatively charged atoms in laser-solid foil ion acceleration setup has been sometimes observed, although no completely explored yet. In this project the creation of such charge states were studied by a controlled preplasma or by having accelerated particles propagated through a gas jet.

Primary objective: create exotic charge states (negative, loosely bound) among the laser accelerated ions, by changing the preplasma conditions on the illuminated surface of the solid target (as observed in previous experiments in LOA).



Secondary objective: produce and characterize a beam of accelerated neutral atoms by neutralising the laser accelerated positive charge in an Argon gas jet.

The diagnostic devices put in place are also expected to produce additional informations on the neutral component that is present among TNSA accelerated particles in normal conditions.

Achievements: Primary objective: it hasn't been possible to observe the searched interaction condition, possibly for non sufficient control on the creation of a pre-heating beam, on its energy, on the synchronization and on the spatial superposition with the pump beam.
Secondary objective: it has been possible to produce and characterize a stable beam of neutral carbon atoms, with a maximum energy of 3.6MeV (300 keV/nucleon). Different diagnostics have been installed to ensure the typology of observed particles and to be able to quantitatively compare the neutralized with the non-neutralized signal.

The use of a removable stripper magnet in conjunction with a Time-of-Flight detector and a Thompson Parabola also permitted to conclude that no neutral atoms are accelerated in normal TNSA interaction conditions.

The performed activity permitted to open many issues, from the experimental and from the theoretical points of view, which will certainly be addressed in experimental campaigns to come

v) ICFO – CUSBO

Sending Institution: The Institute of Photonic Sciences, Barcelona, Spain

Hosting Institution: Centre for Ultrafast Science and Biomedical Optics, Politecnico di Milano, Dipartimento di Fisica, Milan, Italy

Duration: 10 days

Participating staff: Simon Wall, Timothy Miller

Objectives of the exchange: We propose to investigate and control ultrafast demagnetization processes in the antiferromagnetic insulating compound Cr_2O_3. Due to the stronger exchange interaction between spins in antiferromagnetic systems, the spin orientation can be manipulated on significantly faster timescales than those found in ferromagnets, making them attractive materials for future devices. We will investigate how the spin system in Cr2O3 can be controlled by ultrafast pulses of light, focusing on comparing the efficiency of the demagnetisation process when the sample is excited by above-gap excitation, leading to a reduction in magnetisation through electron-spin scattering, to that from resonant excitation of magnons, where the spin order is directly perturbed. The system will be probed by both second harmonic generation, which is a direct probe of the magnetic ordering in the system, and sum frequency generation spectroscopy, which is sensitive to the different components that give rise to the magnetic order. This will allow us to separate the relative contributions of the crystal field and spin-spin interactions to the demagnetization process and will provides significant new insights into the processes that govern melting dynamics in antiferromagnetic compounds.

Achievements: The pump-probe measurements performed in Polimi ultrafast spectroscopy lab aim to a better understanding of the demagnetization process in the antiferromagnetic insulator Cr_2O_3. This compound orders antiferromagnetically at room temperature TN=305 K and it displays a gap of 2 eV. The transition from paramagnetic to antiferromagnetic order is accompanied by a change in the crystal structure from centrosymmetric to non-centrosymmetric. This change of structural properties gives rise to a finite second order susceptibility and makes the sample capable to emit second harmonic (SH) signal. Therefore SH generation is a direct probe of the antiferromagnetic order in Cr_2O_3. In order to study how the antiferromagnetic order can be quenched by an ultrashort laser pulse, the sample has been excited in two different ways: by pumping with photon energies above the band gap (Epump=2.4 eV), where the demagnetisation could be destroyed by injecting hot carriers through electron magnon-scattering and below the gap (Epump=1.7 eV) by directly exciting the exciton magnons.

The measured SH transient response displays a markedly different behavior in the two excitation condition, showing that the physical mechanism involved has different origin. In case of above gap pumping, the demagnetization process is characterized by a finite build-up signal (~250 fs) which is followed by a fast decay (of the order of 100 fs) and an extremely slow plateau. For below gap excitation, the build-up signal is within the temporal resolution of the experiment (~150 fs) while the fast dynamics is completely absent. Further additional measurements are required to clarify the physical origin of the antiferromagnetic melting process and will be performed in the near future. In particular the dependence of the SH transient signal by slightly varying the pump energy across the gap will be studied together with the transient reflectivity.

vi) CUSBO – ICFO

Sending Institution: Centre for Ultrafast Science and Biomedical Optics, Politecnico di Milano, Dipartimento di Fisica, Milan, Italy

Hosting Institution: The Institute of Photonic Sciences, Barcelona, Spain

Duration: 8 days

Participating staff: Danilo Bronzi

Objectives of the exchange: The ICFO group has recently developed a new method for three dimensional, non-invasive imaging of deep tissue cerebral blood flow (CBF). Imaging CBF is critical to the diagnosis and monitoring of many diseases. Examples include most obviously stroke and other ischemic injuries – all hemodynamic derangements – and also neurodegenerative diseases such as Alzheimer’s. The proposal targets the adoption of a new, novel detector for extending this technique to applications in humans by pushing the limits of the signal-to-noise ratio using a photon counting camera. This step is enabled because the POLIMI group has developed a unique technology based on single-photon-avalanche photodiodes (SPADs) and is interested in exploiting the technology for biomedical uses. To that end, they have put together a two dimensional, photon counting camera. ICFO group is an expert in biomedical optics and have demonstrated the new tomographic approach in phantoms and in basic in vivo tests (patent pending). Together, the two groups have developed a plan to carry out joint experiments to introduce a new, non-invasive blood flow imaging technology based on laser speckle contrast for human, clinical applications.

Achievements: The SPAD camera from Milano and ICFO tomography systems were customized as proposed. The camera was integrated into the system and an extensive set of measurements were carried out to demonstrate its feasibility on phantoms. The results were compared to the gold-standard diffuse correlation spectroscopy measurements.

vii) CUSBO – ICFO

Sending Institution: Centre for Ultrafast Science and Biomedical Optics, Politecnico di Milano, Dipartimento di Fisica, Milan, Italy

Hosting Institution: The Institute of Photonic Sciences, Barcelona, Spain

Duration: 17 days

Participating staff: Andrea Farina, Edoardo Martinenghi, Antonio Pifferi, Sanathana Konugolu

Objectives of the exchange: The medical optics group at ICFO working with clinicians from Hospital Clinic Barcelona has identified two organs of interest, the thyroid and the manubrium, for non-invasive measurements of microvascular blood flow and oxygenation. Moreover the contemporary in-vivo monitoring of other parameters like lipid and water could be crucial for the non-invasive detection of diseases hosted by the two organs, such as the thyroid cancer, mylenoma and the Grave's disease. The idea is to support diffuse correlation spectroscopy (DCS), used for blood monitoring, with time-resolved diffuse optical spectroscopy (TRS), used for the content quantification of lipid, water and other possible chromophores.

Achievements: ICFO's diffuse correlation spectroscopy system and the device brought from Milano were integrated by a time-sharing approach. Joint experiments were carried out according to the proposal plan. We were able to measure all the proposed components and carry out a pilot study.

viii) CNRS/CEA – LLC

Sending Institution: Laboratoire pour l'Utilisation des Lasers Intenses, CNRS, Palaiseau, France, and CEA-Saclay - SPAM, Saclay, France

Hosting Institution: Lund Laser Centre, Lunds Universitet, Lund, Sweden

Duration: 32 days

Participating staff: Brigitte CROS, Frédéric DESFORGES, Thomas AUDET, Sandrine DOBOSZ-DUFRENOY

Objectives of the exchange: The main objective of this project is to explore in details the mechanisms of ionization induced injection of electrons in laser-wakefield acceleration. The use of ionization-induced injection should allow us to generate electron bunches with a better control and higher charge than the ones commonly produced via self-injection. One of our motivations for studying ionization-induced injection is to increase the betatron fluence for a given laser power, leading to a higher X-ray generation efficiency.

The proposed research intends:

1. to study the dynamics of electrons in different plasma conditions by mapping the X-ray emission zone inside the plasma. The use of capillary tubes allows the generation and diagnostic of electron bunches in a large range of plasma densities and profiles, and consequently a better understanding of the different regimes of ionization-induced injection mechanisms.

2. to explore the possibility of using capillary tubes for reflecting X-rays in order to enhance the peak X-ray fluence, as some results indicate that glass capillary tubes should be smooth enough to reflect betatron X-rays.

Achievements: Investigations of the dynamics of ionization-induced injection of electrons in the laser wakefield non-linear regime were performed by exploring a wide range of experimental parameters such as the type of high Z atoms, their percentage, the gas density profile inside capillary tubes or gas cells and laser power. A large amount of data was produced during this campaign (more than 4000 shots on target) and most of it is still under analysis at this date (December 2014). Main achievements are:

- the measurement of betatron X-rays at the output of glass capillary tubes: the interpretation of obtained X-ray patterns and the determination of the X-ray source properties are underway;

- the measurements of the positions of the laser, electrons and X-ray beams on each shot: their pointing correlation will be quantified; steering the electrons and X-ray beams pointing was achieved by using capillary tubes;

- an extensive study of ionisation induced injection, performed in gas capillary tubes and gas cells, showing that the shape of the electron spectrum can be tuned by controlling the laser propagation in the plasma.

ix) MPQ - CUSBO

Sending Institution: Max Planck Institute of Quantum Optics, Garching, Germany

Hosting Institution: Centre for Ultrafast Science and Biomedical Optics, Politecnico di Milano, Dipartimento di Fisica, Milan, Italy

Duration: 19 days

Participating staff: Sergey Zherebtsov, Hui Li

Objectives of the exchange: We aim to study the evolution of nanolocalized fields with attosecond temporal and sub-wavelength spatial resolution. Depending on the nanoparticle size and material composition we can access different field propagation regimes: for small nanoparticles the quasistatic approximation holds while for particles with diameter comparable to the laser wavelength field propagation effects will result in the sub-wavelength concentration of strong near-fields on the back side of the particle. By combining the attosecond streaking and velocity map imaging (VMI) techniques we will be able to observe with attosecond resolution propagation of ultrashort strong laser fields in isolated nanoscopic systems.

Achievements: We applied attosecond streaking technique to trace the electron photoemission process in isolated dielectric nanospheres with attosecond resolution. A stream of isolated aerodynamically focused SiO2 nanoparticles of 50 nm diameter was delivered into the laser interaction region. Photoemission was initiated by an isolated 250 as pulse at 35 eV and the electron dynamics was traced by attosecond streaking using a delayed few-cycle laser pulse at 600 nm. Electrons were detected by a single-shot VMI spectrometer. This unique tool allowed us to obtain nanoparticle and reference streaking spectrograms from the same experimental data set. The streaking trace for nanoparticles precedes the one from the reference by ~100 as. To interpret the experimental results we performed semi-classical trajectory simulations taking into account the near-fields and electron propagation inside the nanoparticle. The simulations indicate that the delay originates from scattering of the photoelectrons inside the nanoparticle.

x) CELIA – GSI

Sending Institution: Centre Lasers Intenses et Applications, University of Bordeaux, CNRS, Bordeaux, France

Hosting Institution: Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany

Duration: 17 days

Participating staff: Roberto Benocci, Eduardo Roman, Jocelain Trela

Objectives of the exchange: The experiment we propose aims at investigating the non-metal/metal transition associated with the gap closure. This will be done by measuring the optical properties of the compressed material along the Hugoniot up to 1 Mbar. The Phelix beam will be used to generate a planar shock. The thermodynamics of the driven state will be retrieved using conventional and well-established techniques: VISAR and self-emission diagnostics, both time-resolved owing to the use of streak cameras. Moreover, using VISAR data, we will access the reflectivity and refractive index. The reflectivity will be used to monitor the transition from the non-metal (transparent) to the metallic (reflecting) phase. In the regime where water is still transparent, the refractive index will be measured providing information on the microscopic structure of the compressed phase. Finally, experimental data will be compared to results of QMD simulations performed by the theory group involved in this proposal using quantum molecular dynamics. The overall experiment+theory results will provide new data enabling a better understanding of giant and exoplanets structure.

Achievements: Due to the complexity of the employed water targets and in order to fine tuning the VISAR and SOP diagnostic, we first used structured diamond targets with a Nickel step deposition of about 20µm thickness on one side and 20 µm deposition thickness on the other side. The preliminary shots at about 150J (2nd harmonics) proved to be effective to obtain a diamond phase transition from non-metal to metal by analyzing the change of reflectivity of the probe beam of the VISAR diagnostic while crossing the diamond target.

The water targets showed unexpected drawbacks due to the presence of a ghost-reflected beam from the rear surface even at energies for which one would have expected a complete absorbing water phase. This was most likely due to the presence of a poor antireflective coating on the rear side of the targets. At the highest available energies the non-metal/metal transition was not observed. These results need to be confirmed by further analysis of the data, which is in progress.