# LASERLAB-EUROPE

## The Integrated Initiative of European Laser Research Infrastructures V

**Grant Agreement number: 871124**

Work package 3 – NA2 –Scientific and Technological Exchanges

Deliverable D3.3
Intermediate report on "Scientific and Technological Exchanges"

Lead Beneficiary: 30 – LLE-AISBL

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| *Deliverable Type* | | |
|---|---|---|
| R | Document, report | R |
| DEM | Demonstrator, pilot, prototype | |
| DEC | Websites, patent fillings, videos, etc. | |
| OTHER | | |
| ETHICS | Ethics requirement | |
| ORDP | Open Research Data Pilot | |
| DATA | data sets, microdata, etc. | |
| *Dissemination Level* | | |
| PU | Public, fully open, e.g. web | PU |
| CO | Confidential, restricted under conditions set out in Model Grant Agreement | |

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 871124.

# 1 Objectives

The combined scientific and technical expertise of the consortium is a core asset of Laserlab-Europe, making it highly attractive for users and supporting a leading role of European science in photonics research. The objectives of work package 3 are i) to coordinate exchange on crucial scientific and technological issues of relevance for many partners, ii) to address the multidisciplinary applications of lasers and photonics technologies by bridging to relevant ESFRI infrastructures and networks, and iii) to pool know-how and good practice concerning essential operational issues such as security, laboratory management and data acquisition procedures.

# 2 Task 1: "Bridge" Workshops

Task leader: LLE-AISBL

The role of lasers and laser-like sources in modern science and technology is increasing steadily, creating new kinds of infrastructures and pan-European projects, such as ELI and XFEL. Laserlab-Europe promotes clustering and coordinated actions to initiate cross-fertilization with these new infrastructures, in order to avoid duplication of efforts and to strengthen cooperations. Under this task, cross-disciplinary workshops are organised aiming at creating scientific and technical bridges with other communities, dealing with possible issues such as ultra-fast X-ray detection techniques, scientific cases for joint energetic laser/intense X-ray research programmes, etc.

*Science@FELs 2020, 14-16 September 2020, online conference*

The Science@FELs conference is organised biannually by the FELs of Europe collaboration and highlights scientific progress in free electron laser science. It has evolved into one of the most important international conferences in this field. Laserlab-Europe co-organised Science@FELs for the third time.

From 14-16 September 2020 scientists exchanged about most recent results from FELs around the world with a record registration number of over 700 participants for this first virtual conference. Taking place largely in the afternoon for European participants, the schedule allowed also scientists from America and Asia to participate in the sessions.

The virtual Science@FELs2020 conference featured a lively exchange within nine invited sessions across the breadth of FEL science and applications. Presentation topics included imaging, materials science, magnetic and correlated materials, femto-chemistry, catalysis, atomic and molecular physics, bioscience, and laser physics. The conference was accompanied by focus tutorials led by eminent FEL scientists. Furthermore, participants presented most recent results in two poster sessions. While this virtual poster session was a novel experience for everybody, fruitful discussions took place and participants enjoyed the event. During a virtual tour through the FLASH and European XFEL facilities, the participants were also able to witness a behind-the-scenes experience with a live stream from the FLASH accelerator tunnel, experimental halls and laser hutches as well as special insights into all instruments at European XFEL in dedicated videos and Q&A sessions.

*FELs of Europe Tutorials*

At the Science@FELs 2020 conference, the first such conference held online, a small number of focus tutorials led by eminent FEL scientists and specifically addressing younger members of the scientific community were well received. The tutorials introduce hot topics in the field of FEL science with larger depth than usually possible in conference talks. Based on the very positive reception of these tutorials, FELs of Europe has started a regular online tutorial series for young scientists from all over the world inviting distinguished scholars in the field. Laserlab Europe is joining in and suggesting speakers from the network on a regular basis, with a first tutorial by Jens Biegert, ICFO, in April 2022.



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## 3 Task 2: Joint Experimental Programme

Task leader: CEA-LIDYL

The objective of this task is to reinforce the scientific collaboration between Laserlab-Europe partners and to gather their expertise in order to carry out very ambitious research at the forefront of science. Proposals for Joint Experiments, jointly proposed and conducted by scientists from two or more partners, are evaluated by an external selection panel with scientific excellence as the main criterion. The host provides access without charging unit fees.

Until M24, nine “Joint experiments” were performed as listed below, involving 32 scientists from 9 labs. Two experiments had to be postponed due to the COVID-19 restrictions.

a) LULI and GSI, at GSI: “Investigation of efficient ion shock acceleration using high energy lasers in dense gas jet targets and laser-shaped plasmas”
b) LULI and GSI, at GSI: “Optimization of laser-plasma instability based hard x-ray sources” (carried out remotely)
c) MBI and FERMI, at FERMI: “Time-resolved detection of ultrafast optical skyrmion nucleation”
d) MBI and FERMI, at FERMI: “Nonlocal transport phenomena revealed by X-ray transient grating spectroscopy” (carried out remotely)
e) HZDR and LULI, at LULI: “Investigation of C-H-O mixtures in the context of planetary interiors and nanodiamond synthesis”
f) LACUS and MBI, at MBI: “Ultrafast Photoelectron Spectroscopy in solutions of thermally-induced chemical reactions”
g) LIDYL and FERMI, at FERMI: “Charge carrier dynamics of large band-gap MgO material by resonant stimulated XUV raman at the Mg L2,3 edge”
h) LLC and FERMI, at FERMI: “Direct sub-cycle probing of the phase shift induced by two-photon Rabi cycling in helium”
i) MBI and FERMI, at FERMI: “Detecting magnetic texture formation from high-temperature fluctuation phase”

Scientific publications are under preparation.

***Details:***

### *a) LULI and GSI, at GSI: “Investigation of efficient ion shock acceleration using high energy lasers in dense gas jet targets and laser-shaped plasmas”*

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

Hosting Institution: GSI Helmholtzzentrum für Schwerionenforschung Darmstadt, Germany

Visiting staff: Jean-Raphaël Marquès, Livia Lancia, Medhi Tarisien, Fazia Hannachi, Jocelyn Domange, Emmanuel Atukpor

Objectives: Laser based ion beams are promising tools not only for fundamental research but also for industrial applications. The acceleration mechanisms determine the ion beam characteristics and can be optimized to fulfill different requirements in terms of ion energy and flux. In any case, the potential developments depend on the ability of laser facilities to deliver well monitored and reproducible ion beams at high repetition rates. In this context, the use of a gas jet target will allow low debris, relaxed laser operation, thus eliminating the need for replacement of solid targets at high-repetition rate; a major concern for upcoming high-repetition rate high power laser facilities. We have already demonstrated using PICO2000 laser at LULI, proton and He acceleration to energies of 5-6 MeV for protons and 15 MeV for He using near critical gas jet targets produced with supersonic nozzles. This is to our

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knowledge the best result obtained to date with gas jets at infrared lasers. Some peaked structures in the energy spectra are observed probably due to weak shocks randomly distributed in space. Our goal is to demonstrate the possibility to accelerate ions to higher energies (several tens of MeV) by optimizing the electrostatic shock-wave acceleration process with respect to all other processes involved in the interaction. To achieve this goal, we propose to use optical shaping to tune precisely the gas jet characteristics to CSA requirements.

Achievements: The first aim of this proof of principle experiment has been successfully achieved: plasma tailoring of a high density gas jet by the use of colliding blast waves (BW). These BWs were excited by two nanosecond laser pulses focused on two opposite sides of the gas jet. Secondly, we demonstrated that proton acceleration from a high density gas jet is more efficient when the latter is optically tailored on both the entrance and exit sides of the driving ps laser pulse. In addition, a transition from a continuous (exponential) to a peaked energy spectrum is observed when the gas jet is optically shaped. Being a first-time experiment on the PHELIX facility and due to the complexity of the setup, this has been particularly time consuming, and little time was left to optimize the plasma tailoring for maximum efficiency of proton acceleration. We can definitely state that this experiment was globally satisfactory and successful.

### *b) LULI and GSI, at GSI: "Optimization of laser-plasma instability based hard x-ray sources" (carried out remotely)*

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

Hosting Institution: GSI Helmholtzzentrum für Schwerionenforschung Darmstadt, Germany

Visiting staff: Sebastien Le Pape

Objectives: In high-energy density science experiments x-ray probing is also ubiquitous, allowing the measurement of phase transitions, microscopic structure and dynamics through techniques such as x-ray diffraction and scattering. As these applications have high requirements in terms of photon energies and flux, optimization of the laser to x-ray energy conversion is crucial to the success of these diagnostic schemes. Here we propose to use a novel scheme for driving hard x-ray sources with nanosecond laser pulses, which is expected to allow for comparable laser-to-x-ray conversion efficiencies as for the sub-ps high-intensity drivers. In this new scheme electrons are accelerated not by the laser electric field, but rather by strongly-driven plasma waves. The two-plasmon decay (TPD) is the parametric decay of laser radiation into two plasma waves at the quarter critical density. To optimize the X-ray output, we will vary the laser pulse shape and target design.

Achievements: The goal of this experimental campaign was to find the optimum in tern of laser pulse shape and target design to optimize the generation of hard X-ray production using a nanosecond pulse. During the campaign carried out on the Phelix laser at GSI, we varied the laser pulse shape (level of pre-impulsion), target design (different emitting material, adding CH layer onto the emitting coating). A series of X ray and optical diagnostics was used to characterized both x-ray production and optical signal related to Two-Plasmon Decay (TPD) instabilities. We also investigated the impact of the material of the target on X-ray generation going from Copper to Molybdenum and Silver. The trend is similar for also the material, as expected by theory and similar X-ray yield but for silver (which is emitting at higher energy).We then investigated the impact of pre-pulse on X ray yield at lower intensity (using a 300 µm phase plate to increase the focal spot size). In this regime we measured a strong dependance of the X-ray yield with the pre-pulse and laser intensity meaning than the TPD process was further away from saturation. We are now conducting hydro-rad simulations to better understand the experimental trends observed during this campaign.

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### c) *MBI and FERMI, at FERMI: "Time-resolved detection of ultrafast optical skyrmion nucleation"*

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

Hosting Institution: FERMI lightsource, Elettra-Sincrotrone Trieste S.C.p.A, Trieste, Italy

Visiting staff: Bastian Pfau, Michael Schneider, Kathinka Gerlinger, Lisa-Marie Kern

Objectives: Single-shot all-optical switching of magnetization is nearly exclusively realized in particular ferrimagnetic materials. In contrast, we have recently discovered single-shot all-optical generation and annihilation of skyrmions in a ferromagnetic material with strong chiral interactions. Theoretical modeling of the process proposes the nucleation to occur from an intermediate phase at high temperature characterized by magnetic and topological fluctuations. Here, we propose to investigate the time scale of the magnetic reversal in this system and the time-evolution of the transient intermediate states including the correlation length scale of the fluctuations by employing small-angle resonant X-ray scattering. By comparing different magnetic systems, we will also shed light on the role of chiral interaction in all of these phenomena.

Achievements: The goal of this beamtime was to investigate the temporal evolution of skyrmions nucleating in magnetic thin-films following single femtosecond optical laser pulses. We have already established in prior work, that this nucleation process consists of a (thermal) fluctuation phase in which topological charges form, followed by a coarsening phase in which the final magnetic state emerges. In this experiment, we set out to systematically investigate the parameter space spanned by external magnetic field, optical laser fluence and the thermal properties of the samples as well as of the presence or absence of the chiral Dzyaloshinskii-Moriya interaction (DMI). To this end we prepared different Co-based multilayer samples with perpendicular magnetic anisotropy. In advance of the beamtime, we performed synchrotron-based imaging experiments to establish that both multilayer systems support the creation of skyrmions from a mono- or multidomain state using single infrared (IR) laser pulses of picosecond duration. We successfully carried out optical pump / XUV probe experiments with a synchronized external magnetic field. The small-angle x-ray scattering (SAXS) data recorded show the expected signatures of skyrmion nucleation. Furthermore, they reveal distinct differences in the final, as well as the transient states depending on the sample type and external magnetic field applied.

### d) *MBI and FERMI, at FERMI: "Nonlocal transport phenomena revealed by X-ray transient grating spectroscopy" (carried out remotely)*

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

Hosting Institution: FERMI lightsource, Elettra-Sincrotrone Trieste S.C.p.A, Trieste, Italy

Visiting staff: Clemens von Korff Schmising, Kelvin Yao, Martin Borchert

Objectives: We propose to induce, via FEL pulse excitation, transient magnetic structures leading to all-optical switching with periodicities below 100 nm in GdFe alloys. The ultrafast evolution of the magnetization profiles will be probed via a resonant small angle scattering experiment at the Gd N4,5 resonance at 150 eV (8.3 nm). The excitation pattern will be shaped by two interfering FEL pulses at the sample position. A systematic variation of the periodicities of our transient grating structure, will allow us to access spatial dimensions of below 20 nm in order to shed light on ultrafast spin and electron transport on the nanoscale. In this way we also expect that the experiment will establish the fundamental spatial limit of controlling magnetism with light.

Achievements: We investigated a series of GdFe alloys grown on Zr (100nm), $Si_3N_4$ (30 nm) and Polymide (50nm) membranes optimized for high transmission at 150 eV and low surface



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roughness. All samples were previously screened for all-optical switching after laser excitation in our laboratories at MBI, Berlin. Pump pulses with 41.4 nm and 24.9 nm wavelength were aligned to interfere on the sample under a crossing angle of 27.6° and induced transient gratings with ~ 87 nm and 52 nm period. We observed a two-step increase of the diffracted intensity on an ultrafast time scale followed by a slower decay on the order of ~100 ps. For the larger grating of 87 nm we were able to record the 1st and 2nd order simultaneously on the CCD camera and were able to record full time traces for a large number of different excitation fluences. Considering the sinusoidal excitation pattern, the intensity of the second order was surprisingly large, strongly suggesting a nonlinear response of the magnetic film. We currently are carefully investigating the large data set to understand the 1st/2nd order ratios and their temporal evolution as well as to find evidence for magnetization reversal. Finally, we like to note that due to the Corona epidemic, we were not able to travel to FERMI, but instead carried out the experiment as a remote beamtime. The successful completion of this project was only possible because of the excellent support of the FERMI staff.

### *e) HZDR and LULI, at LULI: "Investigation of C-H-O mixtures in the context of planetary interiors and nanodiamond synthesis"*

Sending Institution: Helmholtz-Zentrum Dresden Rossendorf, Germany

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

Visiting staff: Dominik Kraus, Anja Schuster, Katja Voigt

Objectives: The ice giants Uranus and Neptune (U/N) are the least explored planets of the Solar System but are fundamental for understanding how it formed and evolved. Effectively interpreting new data collected by space probes will require reliable interior models, which are to date hampered by the poor knowledge of the elemental mixtures, including C-H-O present inside U/N. The complex chemical properties that these light mixtures exhibit at high pressures (few 100 GPa) and temperatures (few 1000 K) crucially shape the internal structure and evolution of this class of planets and are at the base of unresolved fundamental issues. C-H-O mixtures at relevan conditions can be produced by dynamic laser compression in the laboratory. In turn, the main objective of this project is the measurement of the shock Hugoniot curve as well as reflectivity and thermal emission of $C_{10}H_{16}O_8$ (celulose acetate) and $C_3H_4O_2$ (Cellulose acetate) from 30 GPa up to 400 GPa. This will bring valuable insights in the chemistry of C-H-O mixtures at planetary interior conditions and particularly support the quantitative analysis of corresponding experiments performed at X-ray Free Electron Lasers, which recently observed carbon hydrogen phase separation and the precipitations of diamonds in those materials. Moreover, the experimental setup shall be used to study the recovery of nanodiamonds formed at these extreme conditions, which may be interesting for science and technology applications.

Achievements: As planned, the shock Hugoniot curves of $C_{10}H_{16}O_8$ (cellulose acetate) and $C_3H_4O_2$ (polylactic acid) could be determined from 30 GPa up to 400 GPa. Morevover, reflectivity and thermal emission could be measured for many of these data points as well. Overall excellent data from the Velocity Interferometer System for Any Reflector (VISAR) and Streaked Optical Pyrometry (SOP) was collceted. This data is now being analyzed together with in situ X-ray diffraction data obtained at the Linac Coherent Light Source (LCLS). In addition, several specific samples for diamond recovery were shot at conditions that are promising for diamond formation. These samples are now analyzed in detail ex situ using electron microscopy, Raman spectroscopy and several chemical analysis methods. Overall the data quality is excellent and the data amount is as expected.

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### f) LACUS and MBI, at MBI: *“Ultrafast Photoelectron Spectroscopy in solutions of thermally-induced chemical reactions”*

Sending Institution: Lausanne Centre for Ultrafast Science, Switzerland

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

Visiting staff: Majed Chergui, Luca Longetti, Michele Puppin, Hugo Marroux, Giulia Fulvia Mancini, Oliviero Cannelli

Objectives: The objectives of the proposed joint experiments are first the commissioning of an experimental setup for laser-induced temperature jump (T-jump) monitored by photoelectron spectroscopy probe in solutions, and the time-resolved measurement of a T-jump-initiated substitution reaction in aqueous solutions. The T-jump can be induced in few ps by IR pulses in resonance with the water vibrational bands (1.5 um and 2 um). Hexaaquo cobalt compounds in chlorinated aqueous solutions undergo a reaction, which consist in a progressive substitution of the water ligands by chlorine, as a function of temperature and concentration. The liquid microjet system for PES is able to monitor the Co valence orbitals, which will show spectral transformations along such a reaction. The MBI setup for time-resolved PES in liquids is equipped with a pump-probe setup whith excitation wavelengths extendable into the mid-IR. A time-resolved PES experiment on the cobalt compound in solution with tuneable pump intensity would show the reaction intermediates and products' PE spectra tracking the substitution reaction upon the laser-induced T-jump.

Achievements: The experiment was carried out as follows: 1) experimental conditions for PES with high concentration Co solutions were found during the first week. PE spectra of hexaaquo cobalt solution and the chlorinated solution were recorded. The Co valence band was detected and characterised. The hexaaquo cobalt in chlorinated solution was measured as well at different concentrations and stable experimental conditions were achieved. 2) the commissioning of the pump line for mid-IR wavelengths required to set-up a new delay line with suitable optical elements. Optimal focussing to achieve heating effects on the liquid was challenging (invisible radiation, heat effect was not measurable without carrying out the whole experiment) and it required more time than expected. This took the entire second week. 3) Pump-probe measurements on the solution. Spectral effects due to the pump-probe overlap on the liquid sample were recorded (LAPE), demonstrating the correct experimental conditions for a time-resolved experiment. However, the measured effect of the T-jump was estimated to be too small with the current configuration. The experiment requires some more time to be completed.

### g) LIDYL and FERMI, at FERMI: *“Charge carrier dynamics of large band-gap MgO material by resonant stimulated XUV raman at the Mg L2,3 edge”*

Sending Institution: Laboratoire Interactions, Dynamiques et Lasers, Saclay Laser-Matter Interaction Center, CEA, Saclay, France

Hosting Institution: FERMI lightsource, Elettra-Sincrotrone Trieste S.C.p.A, Trieste, Italy

Visiting staff: Hugo Marroux

Objectives: Resonant Stimulated XUV Raman Scattering (RSXRS) spectroscopy is a promising new method for studying electronic excitations, but it awaits a proof-of-principle showing its capability to unveil specific photodynamics in solids. In particular in large gap insulators whose excited states are difficult to reach due to their energies and/or selection rules. A case in point is MgO, whose optical band gap (BG) lies at ca. 6.2 eV. Directly generating bound (excitons) or uncorrelated (free carriers) electron-hole pairs by excitation from the VB using short pulse lasers is a serious challenge, if one is interested in the ultrafast dynamics of free charge carriers. This is however feasible using RSXRS at the magnesium L2,3 edge located at approximately 49.5 eV. The stimulated Raman process will be operated



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using a phase locked two pulses sequence where one pulse is resonant with the core transition while the second one is downshifted by the BG energy. The resulting BG excitation will be detected following the in-gap visible photoluminescence (PL) of the sample due to defects. This luminescence is known to be fed by excitation at and above the BG. This PL will be monitored with and without the dump pulse, and as a function of the latter's energy. As an additional monitor of the population reaching the bottom of the conduction band and eventually, the formed bound exciton, we will also use single-colour (780 nm) transient absorption as a means to determine charge carrier cooling in this material.

Achievements: The experiment is very complicated and requires precise calibration of the FEL diagnostics in order to know precisely the energy of each harmonics. The beamtime at FERMI consisted of careful calibration of photocurrent recoded on the FEL's focusing mirror, spectrometer readout, and fluorescence. The data analysis is still ongoing but the calibration seems to be consistent. The next step will be to assess if the stimulated Raman process occurred in our sample.

### *h) LLC and FERMI, at FERMI: "Direct sub-cycle probing of the phase shift induced by two-photon Rabi cycling in helium"*

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

Hosting Institution: FERMI lightsource, Elettra-Sincrotrone Trieste S.C.p.A, Trieste, Italy

Visiting staff: Johan Mauritsson, Samuel Bengtsson, Emma Simpson

Objectives: The key objectives of the proposal were twofold:

1) demonstrate the ability to obtain sub-cycle extreme ultraviolet pump – infrared probe resolution at FERMI by utilizing shot-to-shot phase tagging of correlated, infrared-induced photo-electron emission sidebands

2) directly probe the phase induced by two-photon Rabi cycling between the 2p and 5f states in helium through the observation of the sub-cycle phase change.

In order to fulfil the two objectives, the frequency of both the free electron laser and the SLU had to be tuned outside the normal operation. The SLU frequency was tuned to 876.5 nm and the free electron laser was set to generate 4 harmonics seeded around 292 nm..

Achievements: The experiment worked very well. We demonstrated the first objective with the correct frequencies. We are currently analysing the data, but can already now confirm that we see an effect of being close to the 2p resonance. We understand that the parameters in this experiment was outside the normal operation and are very pleased with all the support we got from the staff and are happy that it worked as well as it did.

### *i) MBI and FERMI, at FERMI: "Detecting magnetic texture formation from high-temperature fluctuation phase"*

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

Hosting Institution: FERMI lightsource, Elettra-Sincrotrone Trieste S.C.p.A, Trieste, Italy

Visiting staff: Bastian Pfau, Christopher Klose, Rein Liefferink, Kathinka Gerlinger, Michael Schneider

Objectives: A single femtosecond laser pulse can generate an extended stable skyrmion phase in a thin ferromagnetic layer. The topological phase transition proceeds through an intermediate high-temperature phase which is characterized by magnetic and topological fluctuations. While for Co/Pt multilayers, first experiments have shown that magnetic textures emerge on an unexpectedly fast timescale of 300 ps, the dynamics remain still unresolved



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for multilayers with chiral interaction. Here, we investigate how the competing magnetic interactions drive the texture formation in the fluctuation phase in order to find the speed limits of the ultrafast transition. By comparing different magnetic systems, we also shed light on the role of chiral interaction for the magnetization dynamics.

Achievements: We performed time-resolved small-angle x-ray scattering experiments at the DiProI end-station of the FERMI@Elettra free-electron laser. The experiments comprised a repeatable pump–probe cycle of infrared (IR) laser excitation and subsequent extreme ultra-violet probing. Between each cycle, the sample's magnetic state was reset by switching an external magnetic field. We recorded high-quality, time-resolved data on three different ferromagnetic multilayers with, and without, chiral interaction. In all samples, we were able to detect a transient dynamic signal which we attribute to the topological phase transition, incited by the IR excitation. The data recorded reveals a dynamic that is several orders of magnitude slower in samples with chiral interaction, compared to samples without. The data further shows that transient magnetic structures do exist after excitation, even when a stable final skyrmion state is suppressed by a constantly applied magnetic field. From the experimental data, we were able to extract characteristic values that are well suited for comparison with theoretical models. Detailed theoretical modeling of the processes involved is still ongoing.

We previously encountered the problem that not all samples could be magnetically saturated between pump–probe cycles with the maximum external field available in the experiment. This issue, as well as the general signal-to-noise ratio achievable, were now addressed successfully by the development of optimized multilayer compositions.

## 4 Task 3: Staff exchange

Task leader: LLE-AISBL

Staff exchanges aim at i) improving specific experimental skills and competences for Laserlab-Europe scientists, and ii) assuring that the operators and technicians of Laserlab-Europe infrastructures are trained at the highest possible level through sharing of expertise, procedures and knowledge. Regular calls for proposals are issued. Support for staff exchanges is granted for proposals positively evaluated by a committee of experts under supervision of the Networking Board.

During the first 24 months, Laserlab-Europe has issued two internal calls for proposals for staff exchanges. A Project Selection Panel, composed of representatives of the different Laserlab boards and of one User Representative, was set up to evaluate the proposals. The following criteria were applied:

- 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.

For each proposal, the applicants explain how the proposed visit(s) will lead to a significant transfer of knowledge and/or good practices between Laserlab-Europe partners. Out of the 15 applications received, ten were found to be well justified and perfectly in line with the aims of the call and were selected for implementation. The approved exchanges involve 12 technicians and scientists from five laboratories being trained at six different host institutions. Due to the COVID-19 restrictions, travelling and on-site training had become impossible or largely restricted during the period in question, so that the validity of the approved proposals in 2020 has been extended first by one year, and then for all approved proposals again by three months until the end of March 2022. After selection, one proposed exchange was cancelled due to internal reasons.

First exchanges currently are under preparation. The next call will be issued in M25.

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# 5 Task 4: Joint JRA meetings

Task leader: POLIMI

While Joint Research Activities foster collaboration among well-defined sub-groups of Laserlab-Europe partners on specific research objectives, joint JRA meetings are open to all partners and provide a platform for sharing knowledge and experiences on a consortium-wide level as well as for stimulating further joint activities. Joint JRA meetings are, therefore, an efficient means to induce an important leverage effect on the knowledge and know-how created within the JRA groups, to spread the knowledge throughout the entire Laserlab-Europe community and to create a cross-fertilisation impact.

The first Joint JRA meeting had been foreseen to take place towards the end of the first reporting period, which has not been feasible due to the COVID-19 restrictions. Even though many individual JRA task meetings have been held online successfully, the JRA board and the JRA task leaders agreed that a joint JRA meeting with more than 100 expected participants will only reach the aims as indicated above if held as an in-person meeting. Currently, the joint JRA meeting is planned to be held in July 2022, organized by GSI, Darmstadt, Germany, i.e. before the end of M32. A corresponding postponement of the deliverable as part of an amendment of the grant agreement is under preparation.

# 6 Task 5: Thematic Networks

## 6.1 Task 5a. Network on Extreme Intensity Laser Systems (NEILS)

Task leader: GSI jointly with CLPU

The Laserlab-Europe access-providing facilities include mid-scale high-energy laser systems requiring dedicated well-trained staff for operation, maintenance and operational readiness. Such facilities are found in many of the Laserlab-Europe partner countries: the Czech Republic (PALS), France (LULI2000, APOLLON and LMJ-PETAL), Germany (PHELIX, DRACO), Spain (VEGA) and United Kingdom (VULCAN, ORION). They comprise various frontier technologies pushing peak power and peak intensity delivered either in long (nanosecond) kJ-class or in ultrashort (femtosecond) PW-class laser pulses. While operating parameters between the laser facilities vary, core operational and technical issues such as pulse diagnostics, optics handling, target fabrication, etc., are of crucial importance to all of them. The NEILS network has established a regular laser science forum with meetings where participants can share knowledge and develop best practices.

The first meeting had been initially scheduled for June 2020 at GSI, Darmstadt, Germany, but had to be cancelled. As the meeting should include hands-on experience, a replacement by online solutions is not possible and this NEILS meeting will be organised as soon as travelling will be possible.

In order to keep the collaboration in the NEILS network active, a different format and topics for an all-online workshop have been discussed, resulting in the organization of the event described below.

*Network on Extreme Intensity Laser Systems (NEILS) meeting on facility operation during COVID times, 24-25 November 2021, web meeting*

GSI/PHELIX hosted the first NEILS meeting of Laserlab-Europe V as an online meeting. It was the occasion for 52 scientists, engineers and technicians from the Laserlab-Europe facilities to meet and exchange on their experience about running mid-scale laser facilities in times of the pandemic. In addition, guests from the Institute of Applied Physics of the Russian Academy of Science participated as part of the exchanges with the CREMLIN+ network.



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As an introduction to the meeting, the representatives of three new facilities, namely the laser facilities of ELI ERIC, the HIBEF lasers at the European XFEL and the upgrade of the Matter at Extreme Conditions instrument at the SLAC National Accelerator Laboratory in the USA, gave an overview of these projects. The particular mode of access of ELI ERIC, i.e. excellence-based, mission-based and proprietary access, were explained and details on more and more of ELI's installations coming gradually online were presented. Following that, ELI's representative described the IMPULSE project, which fosters developments towards routine operation and widening user access, a regular topic of exchange of NEILS. HIBEF contributions were an update on the operation and performance of the RELAX laser as well an outlook on ongoing and future upgrade and extension projects. In addition to the technical aspects, the MEC SLAC contribution also introduced the LaserNetUS network. It was the occasion to discuss parallels and differences with Laserlab-Europe.

On the second day the meeting continued more in its traditional style of discussion rounds. After a short update of the NEILS facilities, participants reported also on numerous improvements to the facilities and new projects despite the complicated situation during the pandemic.

The discussion then shifted to the core topic of the workshop, namely the impact of COVID on operation. Overall, the facilities tried their best to adapt to the ever-evolving situation. A challenge arose from the different time scales between the speed of evolution of the pandemic and the resulting regulations and the time scale of the experiment cycles. Generally, teams tried to maintain the level of quality of their operation via stretching working hours and the number of days dedicated to experiments. Because of that, the facilities had to cut on maintenance time and reduced the number of experiments that could be conducted.

The participants addressed the topic of staff-assisted and remote experiments in detail, with various experience sharing and lessons-learned action items. Some of the Laserlab-Europe facilities have established long since an almost completely remote mode of operation (Orion), i.e. with very few or no external users on site, but the majority of the laboratories do not offer this on a regular basis. Overall, it was acknowledged, that for the mid-scale laser facilities remote access is not feasible and therefore can only be offered as staff-assisted access, in order to maintain the high scientific quality of the experiment output. An exchange on the pre-requisites for such a mode of operation took place with the conclusion that dedicated staff and functionalities in the facilities need to be developed.

At the end of the meeting, a live virtual laboratory tour was offered by GSI to all participants.

## 6.2 Task 5b. Network on Data Analysis in Imaging and Spectroscopy (NAIS)

Task leader: ILC

The aim of this thematic network is to boost effectiveness, to foster synergies and to establish a regular forum in which knowledge about data acquisition and information extraction methodologies in imaging and spectroscopy are discussed, improved and exchanged. NAIS focuses especially on overlapping applications such as spectral imaging where an image is treated as multi-modal photon-distribution dataset, obtained from simultaneous measurement with spectral, spatial and temporal resolution. Activities are also dedicated to advanced data analysis techniques as well as to data extraction methods, etc.

The NAIS thematic network complements Laserlab-Europe's Joint Research Activities where developments of specific imaging techniques are playing a central role. It also fosters links to related communities (such as FELs, ESMI or Euro-BioImaging), thus significantly boosting European imaging expertise and leadership.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 871124.

*Laserlab-Europe: Network on Data Analysis in Imaging and Spectroscopy - Kick-off, 30 March 2021*

Due to the COVID-19 pandemic, the kick-off meeting had first to be postponed but was finally held as video meeting on 30 March 2021. 45 participants from 19 Laserlab-Europe partner institutions attended the meeting. Following presentations of the groups/labs on their specific fields of interest, joint activities and internal organisation were discussed. Sub-groups on different topics and methods, which would include a cross-disciplinary approach, are suggested. A series of mini-workshops is planned, and several labs joined in the efforts to organise an online hands-on user training event on data analysis in imaging and spectroscopy (WP4). Regular online and in-person round table meetings are planned that aim at informing the entire group about specific problems and solutions.

## 6.3 Task 5c. Network on Data Management (NEDA)

Task leader: HZDR

Open access to research data and in particular to data underlying scientific publications represents a cornerstone of modern and future science and technology. Adequate data management is thus imperative to ensure that the FAIR principles apply, i.e. that data is findable, accessible, interoperable and reusable. While networks of analytical facilities such as the accelerator-based light sources or the neutron sources communities are faced with the challenge to handle large volumes of data, reaching sizes that render easy transport by the individual users impossible, the Laserlab-Europe community is composed of a multitude of facilities of very different character and size with different individual requirements and approaches to data management.

In order to assess the status of data policies at the different partner facilities and to see how the facilities engage in research data management on the national level, two surveys have been conducted in April/May 2020 and in May 2021. The first survey contained the following questions:

1. Does your lab/institution have a Data Policy and, if yes, which?
2. Do you need a Data Management Plan for national research projects?
3. Does your lab/institution have a central data repository?
4. Does your lab/institution have a Metadata catalogue?
5. Do you use a community standard format for data storage?
6. What types and formats of data does your research generate?
7. Are you requested to make research data publicly available (Open Data)?
8. Do you expect your research data to be re-used?

The results and details are given in the data management plan (deliverable D3.1). The second survey addressed the management of data generated by the various JRA tasks, detailed in the update of the data management plan in the first periodic report.

In order to exploit synergies and to avoid duplication of efforts, collaboration and exchange of best practices with ELI is being pursued, in particular regarding the identification of data suitable for open access provision, investigation of the extent of metadata sets and definition of standardised data formats to ensure interoperability.

*Better Data for Better Science - Laserlab- Europe, CASUS and ELI Workshop, 28-29 October 2021, online event*

Laserlab-Europe, ELI and CASUS - Center for Advanced Systems Understanding - organised a workshop on research data handling and analysis challenges on the mornings of 28-29 October 2021 (online). 85 participants attended the event.


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The diversity in applications, experience and facility size in the Laserlab-Europe community is both a challenge and a virtue for this subject. The workshop presented existing efforts and landscape on data management as well as the needs of the scientific community and the future challenges and opportunities. The main goal was to identify and develop use cases that can valuably adapt to every class of laser facilities.

The first day opened with a welcome note of Sylvie Jacquemot, the Coordinator of Laserlab-Europe. Andrew Götz (ESRF), the coordinator of the PaNOSC project, introduced the topic of the workshop, with a talk on the importance of a scientific data management system. Andrew Götz also pointed out the need for research infrastructures to have a data policy that offers guidelines to staff and users and ensures the appropriate management of the data. Joy Davidson presented the FAIRsFair project (H2020), that supports the implementation of the FAIR principles and uptake of good practices. Since there are currently various different policies that are influencing the way research is carried out, one of the first tasks of the project was to produce a policy landscape analysis that then led to a number of general recommendations on data policies. To support the recommendations FAIRsFair has developed a Policy Support Programme to review policies against recommendations, a certification of trustworthy repositories and training education and support. Stella D'Ambrumenil from PaNOSC/ESS then introduced PaN-Learning, the Photon and Neutron E-learning platform that hosts free education and training for scientists and students and the training catalogue, with training materials for the photon and neutron community.

The second session of the first day resumed with the presentation of Oonagh Mannix (HZB) on the Helmholtz Metadata Collaboration (HMC), that aims at making all Helmholtz data FAIR (Findable, Accessible, Interoperable and Reusable) by promoting the qualitative enrichment of research data through high quality metadata. The last two presentations of the morning focused on HELIPORT, Helmholtz' scientific Project Workflow Platform, and its use case POLARIS. Guido Juckeland from HZDR presented the HELIPORT project that aims at developing a platform, which accommodates the complete life cycle of a scientific project and the data it generates and links all corresponding programmes, systems and workflows to create "FAIR" compliant metadata. Oliver Knodel from HZDR highlighted the practical application of HELIPORT by the experiment POLARIS at HI Jena. The complete data life cycle workflow of the POLARIS experiment has been managed through HELIPORT

A round table discussion focussed on the possibility of identifying common data object definitions and different metadata approaches in the Laserlab-Europe community.

During the second day, Teodor Ivănoaica and Birgit Plötzeneder from ELI presented data management at ELI as a collection of practices that help to plan, collect, process, analyse, preserve, share and make data re-usable. Most importantly, ELI's data management aims at answering actual questions from the scientists and the users. Julian Hniopek from Leibniz IPHT focused his presentation on the FAIR combination of diverse experimental data in specialised repositories, highlighting the lack of interoperability among them. Moreover, he emphasised the need to standardise metadata to allow that results are transferred between labs. Teodor Ivănoaica and Lajos Schrettner, from ELI ERIC and ELI ALPS, presented data policies supporting the FAIR standards and experiment reproducibility challenges.

The last round of presentations focused on the users' experience and the challenges of the management of large datasets, with "real-life" examples from the Laserlab-Europe consortium. Daniel Rolfe from CLF presented the challenges in the OCTOPUS (Optics Clustered to OutPut Unique Solutions) imaging cluster, with huge computational and data issues, a large and growing variety of imaging and analysis modalities and tools, increasing quantities and varieties of studies/samples. Thomas Bocklitz from Leibniz-IPHT described the entire data life cycle of optical/photonic data from generation to the data analysis, data archiving up to bio-medical information. Giacomo Mazzamuto from CNR-INO explained the image processing and management of large datasets in light sheet microscopy, with a focus on big data challenges in whole brain imaging.

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During the second roundtable the discussion focused mainly on the different perspectives of users and infrastructures and electronic logbooks. Also, follow-up activities were discussed, such as setting up a working group / forum for continued discussion on common issues, regular web meetings on specific issues as well as the preparation of a DMP framework.

The presentations of the talks are available at
https://www.laserlab-europe.eu/events-1/laserlab-events/2021/data-management

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## Agenda

| Time | Topic | Presenters |
|---|---|---|
| | **Laserlab-Europe / ELI/ CASUS Workshop**<br>**Better data for better science**<br>**28-29 October 2021, 9:00 – 13:00h**<br>https://www.laserlab-europe.eu/events-1/laserlab-events/2021/data-management | |
| Time | Topic | Presenters |
| | **28 October** | |
| | Session chair: Sylvie Jacquemot, Laserlab-Europe | |
| 09:00 | Opening Session | Sylvie Jacquemot, Laserlab-Europe |
| 09:10 | The importance of a scientific data management system/DMP | Andrew Götz, PaNOSC Coordinator/ESRF |
| 09:40 | Data Policies supporting the scientific community | Joy Davidson, FAIRsFAIR/University of Glasgow |
| 10:10 | Learning Management Systems (LMS) - Better training leads to better operations and better science | Stella d'Ambrumenil, PaNOSC/ESS |
| 10:40 | Coffee Break | |
| | Session chair: Michael Bussmann, HZDR/CASUS | |
| 11:00 | Helmholtz Metadata Collaboration Platform | Oonagh Mannix, HMC/HZB |
| 11:20 | HELIPORT (HELmholtz SCientific Project WORkflow PlaTform) | Guido Juckeland, HZDR |
| 11:40 | HELIPORT use case POLARIS: Integration of a High Intensity Laser in a complete data life cycle workflow | Oliver Knodel, HZDR |
| 12:00 | Round Table "open discussion on expert platforms" | Moderator: Andrew Götz, PaNOSC Coordinator/ESRF |
| 13:00 | End of meeting - day 1 | |
| | **29 October** | |
| | Session chair: Dusan Chorvat, ILC | |
| 09:00 | Data Standards and Data Strategy | Teodor Ivănoaica, Birgit Plötzeneder, ELI |
| 09:30 | FAIR combination of diverse experimental data in specialized repositories - Challenges and possible solutions? | Julian Hniopek, Leibniz-IPHT |
| 10:00 | Data Policies supporting the FAIR standards/experiment reproducibility challenges | Teodor Ivănoaica, Lajos Schrettner, ELI |
| 10:20 | Coffee Break | |
| | Session chair: Annie Klisnick, ISMO | |
| 10:40 | Past, Present and Future of Data in Biophotonics | Dusan Chorvat, ILC |
| 11:00 | Data challenges at the CLF | Daniel Rolfe, CLF |
| 11:20 | Optical/photonic data science: the journey from optical/photonic data to bio-medical information | Thomas Bocklitz, Leibniz-IPHT |
| 11:40 | Image processing and management of large datasets in Light-Sheet Microscopy | Giacomo Mazzamuto, LENS |
| 12:00 | Round Table "open discussion on electronic laboratory book and online experiment documentation" | Moderator: Bernhard Zielbauer, GSI |
| 13:00 | End of meeting – day 2 | |

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