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<i>Deliverable Type</i>		
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.	
<i>Dissemination Level</i>		
PU	Public, fully open, e.g. web	PU
CO	Confidential, restricted under conditions set out in Model Grant Agreement	



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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 the European 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 cooperation. 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 is held every two years by FELs of Europe, a collaboration of the free electron laser facilities in Europe, and has evolved into one of the most important international meetings in FEL science. Laserlab-Europe co-organised Science@FELs since 2016.

Science@FELs 2022, 19-22 September 2022, DESY/European XFEL, Hamburg, Germany

The 2022 Science@FELs conference was held at DESY and European XFEL in Hamburg in September 2022 with nearly 150 participants in attendance from 12 countries.

Following the online conference in 2020, it was exciting to meet so many visitors in person again in Hamburg and discuss recent achievements and developments in FEL science and



applications. The conference addressed a diverse range of topics from biology and chemistry, to theory and FEL engineering and fostered exchange on multidisciplinary approaches. To bring PhD students and young postdocs into the field, the conference started out with three dedicated expert tutorials for young researchers, as has become a tradition in this conference series. The programme was completed by tours of FLASH, the soft X-ray FEL at DESY, and by an in-person poster session and reception held at European XFEL accompanied by tours of the EuXFEL experimental hall.

Science at FELs represents a unique opportunity to gather the expertise of the community, and work together to tackle the big challenges facing science at FELs and neighbouring communities today. To acknowledge the exciting contributions of the next generation, FELs of Europe presents the FEL Science and Applications prize to a young researcher under 35. This year's FEL Science and Applications prize has been awarded to Praveen Maroju from the University of Freiburg. Maroju's work primarily focuses on generating and characterising attosecond-duration pulses at soft X-ray free electron laser (FEL) facilities.

Science@FELs 2024, 17-19 June 2024, Paris, France

Synchrotron SOLEIL and Sorbonne University (Paris) organised the Science@FELs conference on June 17-19, 2024. After the previous successful meeting in Hamburg and the exciting new developments and results from these extraordinary light sources, nearly 100 scientists gathered at SOLEIL and Sorbonne University for the Science@FELs Conference 2024. The conference included sessions on the latest new results as well as tutorials on the operation and uses of FEL radiation. The participants could also join tours of relevant accelerator and laser-based sources in the Paris-Saclay area (SOLEIL beamlines, CLIO infrared FEL, ATTOLAB, APOLLON laser facility, Laser Plasma Acceleration at LOA).

The "FELs of Europe Award 2024 on FEL Science and Applications" was bestowed upon Dr. Hiroki Ueda from Paul Scherrer Institut in recognition of his outstanding contributions to the investigation of the non-equilibrium dynamics of spin-lattice coupling by time-resolved X-ray diffraction.

FELs of Europe Tutorials

At the Science@FELs 2020 conference, online focus tutorials led by eminent scientists and specifically addressing younger members of the scientific community had been introduced and were well received. Since then, FELs of Europe organises a regular online tutorial series for young scientists from all over the world inviting distinguished scholars in the field. Laserlab Europe has joined with tutorials from Laserlab-Europe scientists and promotes the events within the community.

The tutorials introduce hot topics in the field of FEL science with larger depth than usually possible in conference talks. The tutorials take place about every other month, either online or in hybrid mode in case of tutorials during the Science@FELs conferences. Many of the tutorials have been recorded and can be made available upon interest.

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.



During the first 24 months, nine “Joint experiments” were performed, involving 28 scientists from 8 labs.

- LULI and GSI, at GSI: “Investigation of efficient ion shock acceleration using high energy lasers in dense gas jet targets and laser-shaped plasmas”
- LULI and GSI, at GSI: “Optimization of laser-plasma instability based hard x-ray sources” (carried out remotely)
- MBI and FERMI, at FERMI: “Time-resolved detection of ultrafast optical skyrmion nucleation”
- MBI and FERMI, at FERMI: “Nonlocal transport phenomena revealed by X-ray transient grating spectroscopy” (carried out remotely)
- HZDR and LULI, at LULI: “Investigation of C-H-O mixtures in the context of planetary interiors and nanodiamond synthesis”
- LACUS and MBI, at MBI: “Ultrafast Photoelectron Spectroscopy in solutions of thermally-induced chemical reactions”
- LIDYL and FERMI, at FERMI: “Charge carrier dynamics of large band-gap MgO material by resonant stimulated XUV raman at the Mg L_{2,3} edge”
- LLC and FERMI, at FERMI: “Direct sub-cycle probing of the phase shift induced by two-photon Rabi cycling in helium”
- MBI and FERMI, at FERMI: “Detecting magnetic texture formation from high-temperature fluctuation phase”

For details, see deliverable D3.3: Intermediate report on “Scientific and Technological Exchanges”

Until M60, 10 more “Joint experiments” were performed as listed below, involving 30 scientists from 6 labs.

- MBI and FERMI, at FERMI: “Detecting novel enantio-sensitive observables in photoionization of chiral molecules”
- CLF and CUSBO, at CUSBO: “Time Resolved Diffuse Optical Spectroscopy for non-invasive analysis of tissues and organs”
- MBI and FERMI, at FERMI: “Direct detection of magnetic fluctuations in high-temperature phase”
- MBI and FERMI, at FERMI: “Snapshot view on ultrafast charge and spin dynamics of light induced ferromagnetism in a 2D magnet”
- MBI and FERMI, at FERMI: “XUV Stimulated Raman Scattering using photon-recoil imaging”
- LACUS and CUSBO, at CUSBO: “Spectroscopic Transient Polarimetry on Proximate Kitaev Spin Liquid”
- CUSBO and LACUS, at LACUS: “Assessing the electronic and lattice contributions to the charge ordering in the quasi-1D material ZrTe₃”
- LACUS and FERMI, at FERMI: “Element-selective vibrational spectroscopy of Fe₂S₂Cl₄ films by impulsive stimulated Resonant Inelastic X-ray Scattering at the Fe M_{2,3} and Cl L_{2,3} edges with chirped detection”
- MBI and FERMI, at FERMI: “Direct detection of magnetic fluctuations in high-temperature phase”
- CLF and CELIA, at CELIA: “Terahertz (THz) production from laser-driven discharge pulses in wire targets”

Details can be found in Annex 1.

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 entire project, Laserlab-Europe has issued five 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. In total, from 49 applications received, 34 were found to be well justified and perfectly in line with the aims of the call and were selected for implementation.

Due to the COVID-19 restrictions, the staff exchanges from the first and second call had been delayed, and several had to be cancelled due to, e.g., changes in staff or changes in local needs. Therefore, in total 22 exchanges have taken place with a duration of 1-2 weeks each. Overall, 258 days of training were provided. The exchanges involved 32 technicians and scientists from 14 laboratories being trained at 12 different host institutions.

Details can be found in Annex 2.

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. In line with the amendment of the grant agreement and the postponement of the corresponding deliverable, the meeting finally was held on 13-14 June 2022 at GSI in Darmstadt, Germany, with 56 participants on site and 32 online (see deliverable D3.2). In addition, the individual JRA tasks organised regular online meetings to ensure successful collaboration.

Intermediate Joint JRA Meeting, 30 May 2023, web meeting

An intermediate Joint JRA meeting was held online during an entire day, where the task leaders of both JRAs presented the most recent research highlights from the Laserlab-Europe JRAs. The discussions afterwards focussed on advanced technologies that were seen as promising in terms of innovation, future collaborations with academy and industry.

Second open Joint JRA Meeting, 27-29 May 2024, Lisbon, Portugal

The final Joint JRA meeting took place in month 54 of the project duration, thus benefiting from the fact that the joint research activities had been carried out successfully over four years and many scientific results have been achieved and published. During that time, several individual JRA task meetings have been held online in order to ensure exchange within the subgroups working on specific tasks. The final meeting was planned as fully open event that provides a



consortium-wide platform for sharing of knowledge and experience and stimulating discussion about further joint activities, and for reaching out to the broader community as well as to industrial partners showcasing Laserlab-Europe's results.

The joint JRA meeting was held as part of the Laserlab-Europe conference on 27-29 May 2024, hosted by IST, Lisbon, Portugal. The three-day event was attended by more than 100 participants from Europe and North America. The programme consisted of five sessions:

- Session 1: Lasers for catalysis
- Session 2: Attoscience
- Session 3: Lasers in a multi-instrumental world
- Session 4a: Lasers for health - Lasers for oncology
- Session 4b: Lasers for health - Lasers for imaging and diagnosing life
- Session 5: Lasers and laser-based instruments for the future

All sessions included talks from Laserlab-Europe representatives on recent developments resulting from joint research activities, talks from users of the transnational access programme on access highlights and talks from companies' representatives giving an outlook on development needs and opportunities from an industrial perspective.

For details, see deliverable D3.4: Second and open joint JRA meeting

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 due to the COVID-19 pandemic. As the meeting should include hands-on experience, a replacement by online solutions was found to be unsuitable and a new concept was designed as partial replacement. A meeting was held online on 24-25 November 2021, during the afternoons in order to allow participation of US scientists. The main topic was operation in times of COVID-19 and in particular issues around remote access and staff-assisted experiments.

For details, see deliverable D3.3: Intermediate report on "Scientific and Technological Exchanges"

NEILS Annual meeting 2023, University of Salamanca and CLPU, Spain, 20-21 April 2023

After a series of remote meetings organised during the pandemic, the return to an in-person meeting in Salamanca is thought to reinforce the networking activities. The aim of the NEILS network is gathering together different European centres to reinforce collaboration and exchange of knowledge. 27 participants from CLPU, GSI, HZDR, CLF, LULI attended the meeting.



The opening session has been dedicated to an update regarding the participating facilities and a survey about laser-driven nuclear fusion by Professor L. Volpe. The four round table topics have been selected out of an extended list prepared by the CLPU staff involved in the organizing committee. The final choice has seen a mixing between the traditional technical discussions with topics related to the next future strategic scenario affecting the NEILS facilities.

Summary of the facility updates session

The Director of the CLPU, Prof. M.D. Frias welcomes the attendees, thanking all the representatives of the NEILS network for joining the meeting and Laserlab Europe for the support supplied to the organization. G. Gatti presents the status of the CLPU showing the main activities, core of the development of the Center, highlighting the project for the construction of a new bunker. S. Götte presents the updated status of the PHELIX laser at GSI, showing a summary of the operation and developments. Moreover, Stefan reports about the kick-off of the European project THRILL, aimed for the development of high repetition rate intense lasers, in collaboration with other partners, including other members of the NEILS group and coordinated by GSI. L. Volpe presents the present scenario of the Inertial Confinement Fusion at the European level after the achievement of the results at the LLNL (US), bringing a new boost to the scientific community and the players connected like the funding agencies and companies. P. Oliveira presents the status and upgrade of the CLF highlighting the EPAC project, implementing a high intensity high repetition rate user facility as a particles source. M. Chabanis, Jordan Andrieu, Yohann Ayoul report about the status of the LULI infrastructure, presenting the three facilities APOLLON, LULI2000 and HERA and their latest advances.



Round table summaries

Round Table 1: Data Management

The topic of data management seems to be very interesting for all the facilities, due to the environmental tendencies (e.g., funding agencies, projects, journals, technological advances etc.). All agree that the high-intensity laser community is still not fully prepared for an Open Data approach, compared to other communities and that some common efforts should be carried out (in line with the workshops organized by Laser lab) in order to unify different approaches. Regarding the use of electronic tools (e.g., logbooks and others), there are different action lines implemented in different laboratories. Many laser laboratories are pushed by the general policies imposed by their institutions (much larger than the laser laboratory) but at the same time can profit from developing teams fully dedicated to such topics. In general, low repetition rate facilities have started a renewal process regarding data management but this looks more critical for high repetition operations, which in many cases is going to be in the next future.

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Round Table 2: Tendencies and Strategies

Many facilities seem to be in a changing scenario and quite a lot of concern is devoted to future strategies to attract users. It would be interesting to have a clear and objective analysis of the



interest of the “market” towards high-intensity lasers. It would be useful also to introduce the capabilities of these laboratories to new communities different from the traditional ones. Even though in many cases there are “competing” strategies among the laboratories, the discussion seems to suggest some common roadmap in many different fields of interest in order to overcome the limitations of mid-scale laboratories and compete with larger infrastructures.

Round Table 3: High Repetition Operations

All the facilities are actively working on the topics discussed in the round table. Some of the facilities have accumulated a vast experience on these topics, even though, clearly, the highest effort on development is devoted by the laboratories able to work at high repetition, since they are not able to use the full potential of the laser source. All the players are moving towards the same goal (at least with some laser systems) of fostering the high repetition in the next future. It seems quite useful being able to share common experiences regarding detailed aspects of the operations that could ease and streamline the development of new lines. Those aspects are typically irrelevant for publications/patents and it is not the core activity of any laboratory, so that it could be a good candidate for extended collaborations

Round Table 4: Getting more from the Network

The facilities agree on the common interest to build up a new network to strengthen and extend the activities initiated with the NEILS. New tendencies in the world of high intensity lasers require extended and strategic collaborations in order to cope with the new challenges of the scientific community and being attractive for the users. A list of different areas of collaboration has been drawn and further discussions will follow in order to strengthen such a proposal. The attendees will inform the decisional levels of the laboratories about these conclusions of the meeting.

NEILS Annual meeting 2024, CLF, Cosener's house and RAL, UK, 22-23 July 2024

The Network on Extreme Intensity Laser Systems (NEILS) brought together several high-energy/power laser facilities, including CLF, GSI, AWE, CLPU, Apollon/LULI, and HIBEF, for technical sessions and networking opportunities. The core of this meeting focused on the presentation of technical and scientific developments in facility-class high-energy laser systems. It also provided a valuable platform to share practical knowledge and operational experiences that are often not included in scientific publications, fostering collaboration among participants. 41 participants attended the meeting.

The meeting opened with updates from all participating facilities, followed by five roundtable sessions on topics selected based on community feedback. As NEILS 2024 marks the final iteration of the workshop in its current format, a proposal was presented to restructure NEILS as an Expert Group moving forward. The conference concluded with facility tours of the CLF.

Facilities update:

The Associate Director of the CLF, Cristina Hernandez-Gomez, welcomed the attendees and provided updates on the new facilities under construction at RAL: EPAC and Vulcan 20-20. Steve Hawkes followed with updates on the current CLF facilities, including the upgrade to the Gemini front-end and the decommissioning of Vulcan. GSI shared insights on current usage trends in their experimental areas, highlighting new developments such as a stretcher design and large adaptive optics, as well as their new project, THRILL (Technology for High Repetition Rate Intense Laser Laboratories). AWE presented their facility update, featuring recent non-traditional user experiments and emphasizing plans for a significant midlife rekit of Orion. CLPU provided a comprehensive report on operational statistics, plans for upgrading VEGA 1 to enable 100 Hz operation, the development of a new 20 Hz PW amplifier, and the addition of a new target area: AREX 2. LULI shared updates on the current status and future roadmap for the Apollon, LULI2000, and HERA systems, including planned upgrades to the 10 PW beamline at Apollon and new diagnostics at HERA. HZDR presented developments on DRACO, PENELOPE, and HIBEF, highlighting recent results such as the LWFA-driven seeded



FEL demonstration and ion acceleration from cryogenic jet targets. They also introduced the HELPMI project, aimed at developing a data standard for LPI experiments.



Group photo at Cosener's house

Round table session 1: Plasma and Lasers Diagnostics versus Beamline Flexibility

The discussion focused on the level of flexibility facilities allow in beamline setups and its impact on both permanent and temporary diagnostic setups. Across most facilities, laser pulse diagnostics tend to be permanent, while plasma diagnostics vary depending on the experiment. Incorporating external equipment into experiments was generally agreed to be complex. At a minimum, equipment must be checked for vacuum compatibility and its ability to operate in a noisy EMP environment. It was widely agreed that more experienced user groups benefit from additional flexibility, whereas fixed geometry setups help manage less experienced users. Inexperienced users often influence planning by overlooking necessary contingencies, which forces facilities to adapt during the experiment. This suggests a need for facilities to address this variation in user experience. The CLF highlighted its approach to mitigating these issues through careful planning and by offering user training prior to experiments.

Round table session 2a: High Power Laser Facility as Drivers for Secondary Sources

The discussion began with a unanimous agreement on the lack of time and resources dedicated to developing secondary sources into "beamline"-like facilities. As access to these facilities is primarily academic-led, there is little direct repetition or consistency between experiments. Advances in electron acceleration were highlighted, with active development in areas such as kBar gas-jet targets and wavefront optimization. There was general interest in moving away from plates and films for x-ray characterization, with some participants working on new active detector techniques. The session concluded with discussions on potential future collaborations in this area.

Round table session 2b: Data Management and Control Systems

Several facilities have either adopted or are considering moving toward standard control system toolkits, such as EPICS or TANGO, with development done in-house or through external contractors. A key topic of discussion was how to effectively manage large projects when contracting out development. Some facilities, heavily reliant on National Instruments software, are taking steps to transition to alternative systems. Additionally, the HELPMI project, which aims to establish a standardized data format for LPI experiments, was discussed.



Round table session 3: High Rep Rate Operations

Maximizing the potential of multi-Hz systems will require closer engagement with users to rethink experimental campaign structures and target setups, as users often do not fully utilize the available repetition rate of current facilities. Machine safety emerged as a key focus for multi-Hz operations, with participants agreeing that small damage sites can quickly escalate into catastrophic failures due to the high repetition rate. Debris and contamination were identified as major challenges for long-term multi-Hz operations, and participants shared valuable practical information on mitigation strategies. Ex situ RF-plasma-based cleaning techniques are already in use at some facilities to restore coating performance between experimental campaigns, while in situ RF cleaning is planned for upcoming facilities. Fast beam pointing stabilization is an active area of development, with some participants exploring machine vision and machine learning techniques. These methods require large volumes of training data, which are only accessible at high rep rate facilities.

Round table session 4: Low Rep Rate Operations

Several facilities are exploring greater operational automation due to staffing shortages. AI-assisted shot start-up processes are being investigated, with PhD projects dedicated to stabilizing focal spots and pulse durations using machine learning. The accelerator community has considerable expertise in this area. However, concerns were raised about machine safety, as automated AO systems could lead to hotspots and potential damage. The transition from film to camera diagnostics was discussed, though it remains a complex challenge. As calibrated filmstock becomes harder to source and its use limits repetition rates, the shift to cameras will eventually be necessary. However, users still prefer film diagnostics due to their reliability and superior dynamic range. Debris mitigation strategies were another key topic, with participants agreeing that effective mitigation should begin at the target design stage. Strategies for increasing repetition rates and improving system stability by running facilities in an "active standby" mode were considered. However, the consensus was that the potential negative impact on system lifespan and operational safety might outweigh the benefits, especially since users often do not fully utilize the current repetition rates available at many facilities.

Round table session 5: Laser Source Technologies

Broadband incoherent sources are a topic of significant interest across the community, with recent developments utilizing SOA (Semiconductor Optical Amplifier) systems. Discussions on front-end architectures revealed that most of the community has transitioned to OPA (Optical Parametric Amplification) or CPA+XPW (Chirped Pulse Amplification + Cross-Polarized Wave Generation) front-ends, which offer broad bandwidth and improved contrast. Strong advancements in commercial front-ends have led to their successful deployment at various facilities, with systems demonstrating high reliability and contrast levels as low as 10^{-12} . However, improvements gained by XPW depend heavily on the setup: simpler schemes showed minor improvements, while more complex setups that incorporated spatial filtering and active DAZZLER compensation achieved significantly better results. Sourcing Nd:Glass remains a challenge due to the limited number of suppliers.

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-Biolmaging), thus significantly boosting European imaging expertise and leadership.

Since the start of the project, the NAIS network held three online meetings. Major discussion items were the organisation of online training events for students in the field. Members of the network jointly organised two online hands-on user training events on data analysis in imaging and spectroscopy, which attracted great interest. A third event on data analysis was organised by the NAIS network as in person meeting at ICFO, Spain. For details on the training events, see deliverable D4.2: Final report on "User Training".

In the framework of the Laserlab Talks, a member of the NAIS network gave a talk on "KiMoPack - A python Package for Kinetic Modeling of the Chemical Mechanism" that met with huge interest in the laser community.

Together with the NEDA network, NAIS organised a joint workshop on electronic laboratory notebooks (ELN), see Task 5c below.

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.

Based on two surveys conducted within the Laserlab-Europe consortium on data policies and research data management (see D3.1 Data Management Plan), Laserlab-Europe partners have prepared and agreed on a common data policy template based on previous PaNOSC activities and on data policies of Laserlab-Europe members. This template is accessible through the Laserlab-Europe website (<https://www.laserlab-europe.eu/publications/data-management>) and has been shared with all consortium members with the recommendation to adapt and use the template if the member organisation does not yet have a data policy.

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

An online workshop on "Better data for better science" has been held jointly with ELI and CASUS (Center for Advanced System Understanding) on 28 and 29 October 2021 (see D3.3 Intermediate report on "Scientific and Technological Exchanges"). 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 four thematic sessions focused on scientific data management, use cases from several institutes, data standards and strategies, as well as user experiences and challenges of the management of large datasets from different research areas. 85 participants attended the workshop.



Workshop on electronic laboratory notebooks, 13 November 2024, online

Based on the feedback received during the workshop on “Better Data for Better Science” and additional input from the Laserlab-Europe consortium, NEDA and NAIS (see Task 5.b) organised a joint workshop on electronic laboratory notebooks (ELN). To prepare the workshop topics, an online survey was shared among partners and JRA participants to get first insights about the needs and expectations from the community. The following questions have been asked:

- If you use electronic laboratory notebooks (ELN), which software do you use?
- Do you use it individually as a researcher or does your institution use this tool?
- Why did you choose this software?
- Do you have concrete questions about electronic labbooks that you would like to see discussed in a workshop?

The online workshop on electronic laboratory notebooks highlighted different tools used by the community. Speakers from Laserlab-Europe, ELI as well as different research infrastructures in Europe and from the user community shared their initiatives and activities. 64 participants joined the workshop online.

Electronic Laboratory Notebooks (ELN) are software applications that allow research data to be recorded, managed and structured electronically. Ideally, they support the entire research process from planning, execution and evaluation of the experiment to publication of the results, and even later for open data reuse.

ELNs have increasingly replaced paper notebooks over the last two decades, but adopting them is challenging; it requires the willingness by all involved to document analyses and experiments differently from their habits. In addition, the multitude of ELN products on the market makes choosing one specific solution complex. To address this complexity, Laserlab Europe organised a workshop where several users presented the pros and cons of many ELNs - eLABFTW, Labfolder, Labtrove -, their experiences with in-house solutions and discussed what questions should be answered when selecting an ELN.

Choosing an ELN is a complex issue, with the conclusion being that researchers must first decide what they can expect from it, how it fits in with their own resources, and what the ELN should make better and easier. In other words, the ideal software application depends on the type of facility or experiment, on the type of data generated and on the tools/equipment used (whose characteristics and parameters need to be integrated).

Experienced users emphasized that without competence, commitment and compliance of all users, as well as appropriate training of the younger researchers, these software applications face the risk of not being worth the effort.

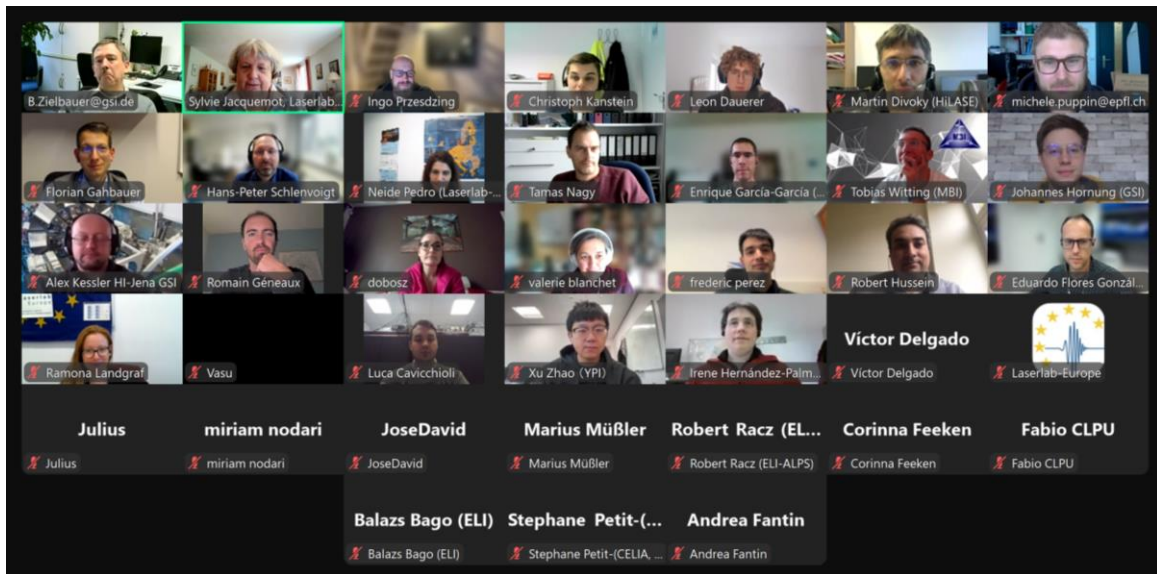
Discussions highlighted that an “ideal” ELN must include a user-friendly interface, proper file management and search tool, as well as extended import-export-migration options. It must allow for secured, GDPR-compliant multiple - simultaneous – online access, be flexible (to track changes along a whole project’s life) and open source. However, there are practical problems with this latter requirement, such as sustainability.

Nevertheless, the fact that these tools significantly reduce the time required to run and document experiments, and improve data integrity and compliance, makes the investment in ELN deployment worthwhile in many if not most cases.

The workshop was a stepping-stone for many of Laserlab Europe's APIs who took the opportunity to gain first hand insight into the ELN market, understand the costs and legal issues they need to be aware of and consider software integration when choosing ELN software.

The ambition now is to plan further follow up workshops where scientists can test the interfaces in a peer exchange, so that institutions looking for an application or looking to upgrade their current software can get a more accurate idea of the products and make a well-informed decision.





Participants in one of the sessions of the e-labbook workshop



Annex 1

Details on Task 2: Joint Experimental Programme

MBI and FERMI, at FERMI: “Detecting novel enantio-sensitive observables in photoionization of chiral molecules”

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

Principal Investigator: Olga Smirnova

Achievements: The goal of our work was to exploit the attosecond phase control offered by phase-locked two-color pulses at FERMI to detect new aspect of molecular chirality : geometric fields in molecular photoionization that we have recently discovered theoretically. It leads to several new classes of enantio-sensitive observables in photoionization, most of the observables in these classes have not been detected so far. Specifically, we focused on tensorial observables which can be detected in crossed polarized phase-locked two-colour fields. The interference of two-photon and one photon photoionization pathways leads to the delay-dependent observable recording enantio-sensitive molecular phase formed during photoionization and fragmentation. This observable has been predicted, but has not been observed experimentally.

Our experiment successfully detected such new tensorial observable: a two-color phase delay dependent tilt in angle-resolved photoelectron spectrum. To achieve this results we performed a systematic scan of the seed wave-length in the region of interest (corresponding to one photon excitation to Rydberg bands) to locate and exploit a specific near threshold "double resonance" features in two photon photoionization spectrum. This features appear if the first photon excites the resonant transition between HOMO and Ry state, while the second photon promotes an electron from lower orbital to the hole in HOMO (the second resonant transition) and appears at 247 nm seed wave-length. To improve our signal and emphasize its dynamical component, we recorded differential spectra corresponding to difference between 247 nm and 246 nm spectra for each two-color delay. The resulting energy and angular resolved spectra were processed to obtain the enantiosensitive and phase sensitive angular offset encoding the molecular phase due to photoionization, formation of highly excited ion and its fragmentation. Thus, our observable not only records the new aspect of molecular chirality (manifested by geometric field in molecular photoionization), but also records the enantio-sensitive molecular phase characteristic to coupled electron-nuclear dynamics in superexcited molecules. We are currently finalizing the analysis of the data and preparing the draft of the paper.

CLF and CUSBO, at CUSBO: “Time Resolved Diffuse Optical Spectroscopy for non-invasive analysis of tissues and organs”

Sending Institution: Central Laser Facility, Rutherford Appleton Laboratory, STFC, Oxfordshire, United Kingdom

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

Principal Investigator: Sara Mosca

Achievements: The key objective of the project is to demonstrate the explore the viability and effectiveness of a new approach combining Spatially Offset Raman Spectroscopy (SORS) with Time Domain Diffuse Optical Tomography (TD-DOT) (Deep RamNIR), to localize and monitor deeply located inclusions (e.g. cancers lesions) tagged with SERS nanoparticles (NP's). Another objective of the proposed project is designing and developing an appropriate model phantom, compatible with both techniques, to properly validate novel technologies before translation to in-vivo subjects. This will benefit a wide range of studies including photon migration in biological



tissues and all its numerous applications such as in vivo tissue diagnosis, bone quality assessment and diffuse optical tomography.

In line with the proposed objectives, during the beamtime week, we prepared and optimised a set of phantoms compatible with the two techniques. We carried out the spectral characterisation (absorption and reduced scattering over the spectral range covered by SORS acquisitions - from 810 nm to 950 nm with 20 nm step) of the bulk materials of the initial phantoms to optimize the parameters for phantom preparation before the tomography measurements. We also carried out SORS measurements in solution at different absorption values (from 0.01 mm⁻¹ to 1 mm⁻¹) and a fixed scattering value of 1 mm⁻¹ to evaluate the attenuation effect on the Raman spectra characterization. With the preliminary information, we managed to perform a tomographic measurement on a cylindrical inclusion ($\mu_a=0.04$ mm⁻¹; $\mu_s'=1$ mm⁻¹ + NPs) embedded in a diffusely scattering matrix ($\mu_a=0.01$ mm⁻¹; $\mu_s'=1$ mm) at depths of 5 mm and 15 mm. We have encountered difficulties in the sample preparation (e.g. the embedded NPs in the diffusive media) and the spectral characterization of the embedded NPs due to sample degradation during transportation (shipping) and also a low optical contrast of the NPs was achieved in the investigated window. Despite these challenges, the first beamtime week allowed us to characterise limitations of the approach and guided us towards the selection and optimization of settings and parameters to progress in the project for future develop of the combined proposed approach. This will include NP's with a stronger plasmon resonance in the region of interest (e.g. resonant dye in the NIR region - SERRS and/or nanorods).

MBI and FERMI, at FERMI: “Direct detection of magnetic fluctuations in high-temperature 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

Principal Investigator: Bastian Pfau

Achievements: The goal of the experiment was to directly detect the spin fluctuations in a ferromagnet in the so-called fluctuation state after photo-excitation. It has been proposed that this fluctuation phase plays a crucial role in forming a topological skyrmion phase. Unlike previous experiments detecting (average) in-plane magnetic ordering based on time-resolved (incoherent) small-angle scattering, detecting temporal fluctuations requires coherent scattering and single-pulse detection. In turn, efficient single-pulse detection at 50 Hz at the DiProl endstation is only possible with the sCMOS detector. Unfortunately, this detector was severely damaged just before our beamtime. Essentially, the damage made detecting the coherent magnetic speckle patterns impossible. Still, we were able to use the detector to verify the topological switching in our samples. In addition, we studied different beam-defining masks prepared on top of our magnetic films, which we used to define a coherence area on the sample and to establish a heterodyne detection geometry. We also recorded data which will give us a more realistic idea about the signal levels we can expect, allowing us to further optimize our scattering geometry and data analysis for an upcoming second beamtime on this topic.

MBI and FERMI, at FERMI: “Snapshot view on ultrafast charge and spin dynamics of light induced ferromagnetism in a 2D magnet”

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

Principal Investigator: Clemens von Korff-Schmising



Achievements: We successfully followed the charge and spin dynamics of the metallic 2D magnet system $\text{Fe}_x\text{Ge}_y\text{Te}_2$ using an experimental geometry based on a two-color, time-streaking off-axis zone plate. Goal was to first test the hypothesis of "optical doping", i.e. the experimental observation that optical excitation can induce a paramagnetic to ferromagnetic phase transition and secondly to observe theoretically predicted spin-polarized electron transfer from Fe to Te, an important first step in interface spin currents in 2D heterostructures. To this end, we investigated two sample systems, small flakes of exfoliated F3GT, and F5GT systems grown by molecular beam epitaxy, the latter being ferromagnetic at room temperature. We were able to measure the charge/spin dynamics across the Fe and Te edge for 10 distinct photon energies. The excellent signal to noise ratio of the zone plate experiments allowed us to reveal complex dynamics, which are currently being analyzed, aided by ab-initio calculations.

MBI and FERMI, at FERMI: "XUV Stimulated Raman Scattering using photon-recoil imaging"

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

Principal Investigator: Ulli Eichmann

Achievements: We proposed to investigate XUV Stimulated Raman Scattering via autoionizing resonances into a metastable state in He and Ne on an individual atom level using two FEL pulses. Direct position-sensitive detection of the metastable atom allows for distinction between spontaneous and stimulated processes via their deflection. We experimentally demonstrated that two-color stimulated Raman transitions (SRTs) with coherent XUV pulses to the He^* metastable singlet state (to excited states of Ne) can be detected and studied by the proposed method almost background free and, surprisingly, with a relatively high detection efficiency. By tuning the photon energy of the seed laser across the resonance, we were able to take spectra of the stimulated Raman process not only for a single pair of harmonics, as suggested in the proposal, but for four different pairs. Theoretical analysis of the results, which are expected to reveal how far strong field effects result in line shifts, is pending. The occurrence of stimulated Raman scattering was unambiguously proved by changing the polarization of the two harmonics from being both right circularly polarized, where strong He^* yield was observed, to one harmonic left and the other one right circularly polarized, where the yield decreased by a factor of 50, as expected from dipole selection rules.

LACUS and CUSBO, at CUSBO: "Spectroscopic Transient Polarimetry on Proximate Kitaev Spin Liquid"

Sending Institution: Lausanne Centre for Ultrafast Science, Switzerland

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

Principal Investigator: Hui-Yuan Chen

Achievements: Our goal is to investigate photoexcited inter-site dynamics in a Kitaev honeycomb iridate, $\alpha\text{-Li}_2\text{IrO}_3$, at two representative phases: proximate spin-liquid (PSL) regime (12K–66K) and spiral antiferromagnetic (AFM) phase (<12K). Using the versatile broadband transient reflectivity (TR) setup in the Stratus laboratory at CUSBO, we can access the non-equilibrium inter-site dynamics via distinct photoexcitation regimes. By examining polarization dependence on the transient reflectivity for both PSL regime and AFM phase, we will be able to delineate the influence of bond-directional interaction Kitaev interaction in honeycomb lattice. It has been suggested that such PSL regime remains up to at least five-fold of the Neel temperature. This implies certain residue of anisotropic Kitaev interaction is



present within those temperature. Since kinetic exchange interaction (virtual hopping) and electron transition (real hopping) share correlated underlying physics origin, the bond-directional interaction entailed in Kitaev materials could manifest itself in inter-site transition that is readily reachable with tabletop optics. Therefore, we adopted broadband transient reflectivity to study this Kitaev material with pump polarization dependence. By optically dressing the superexchange with distinct excitation energies and dynamically probing accordingly, it allows us to interrogate the Kitaev physics through inter-site transition dynamics.

To systematically study the ultrafast inter-site transition dynamics in α -Li₂IrO₃, we have measured the transient reflectivity of the single crystal sample in the near-infrared spectral range between 1.0eV and 1.4eV, covering several electronic transitions. Distinct transient response, observed upon the excitations across the Mott gap (0.8eV) and the charge transfer gap (3.1eV) in the two respective magnetic phases, clearly indicates that both electronic and magnetic degrees of freedom are affected differently by the compared electronic excitations. We have further performed a temperature dependence in the 4–120K range. Whereas the transient signal on the sub-picosecond time scale remains mostly unaffected by the sample temperature, the picosecond dynamics shows a strong alteration, allowing us to disentangle the timescales of electronic and magnetic changes in the photoexcited system. Moreover, the differences in the spectral shape of the signal extracted from the excitation energy and temperature dependences imply different origins of the probed transitions. The main difficulties encountered during the experiment are related to the small lateral size of the sample and the heterogeneity of the surface, requiring a high stability of the cryostat, and the low reflectivity of the sample, being at the limit of the used InGaAs CCD sensitivity. Because of the latter reason, the signal-to-noise ratio has not been sufficient to systematically investigate the differences in the polarisation-resolved measurements.

CUSBO and LACUS, at LACUS: “Assessing the electronic and lattice contributions to the charge ordering in the quasi-1D material ZrTe₃”

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

Hosting Institution: Lausanne Centre for Ultrafast Science, Switzerland

Principal Investigator: Alberto Crepaldi

Achievements: Main objective of this proposal was to explore the electron dynamics in the quasi-1D state of ZrTe₃. This material has a charge density wave (CDW) ground state developing below 63 K, so we wanted to compare the out of equilibrium response of the material at different temperatures, in particular above and below the transition temperature, and in different zones of the Fermi surface. Indeed, ZrTe₃ has states with different dimensionalities contributing to its Fermi surface: a 3D state around Gamma and a quasi-1D state at the Brillouin zone edge. As first thing we explored the electron dynamics in the 3D state around Gamma, and then compared this HHG study with the trARPES experiment performed in our home laboratory with 6 eV probe energy. From our previous static ARPES study and published literature on this material, we know that the quasi-1D state is the most affected by the CDW phase transition, with a spectral weight redistribution and the opening of a pseudo-gap at the D point. For this reason, the main part of the beamtime was dedicated to the investigation of the out of equilibrium response of the quasi-1D state. To investigate the electronic dynamical response in the normal and CDW phases, with different pump fluences, and different probe polarizations. Our final goal was to observe signatures of the CDW related Amplitude Mode, that develops only in the low temperature phase and whose existence was already confirmed by all optical techniques.

The general outcome of the project is positive. We managed to measure several samples of ZrTe₃ and we acquired meaningful datasets. We measured the out of equilibrium dynamics of the system at room temperature, 77 K (liquid Nitrogen cooling) and 20 K (liquid Helium cooling), thus exploring both the normal phase and the CDW ground state. We used a photon energy of 20.9 eV for the probe pulse, from the HHG set-up, and an excitation energy of 1.5 eV for the pump



pulse. In this way, we were able to access both the 3D state around Gamma and the quasi-1D state at the D point, studying the evolution of the electron dynamics at different temperatures. In particular we have resolved a photoinduced energy shift of the band structure and different coherent oscillations in the relaxation dynamics. We could characterize the photoinduced energy shift by performing pump fluence scans at a fixed delay time and at different temperatures. We revealed that the different frequency components of the coherent oscillations are not affected by temperature or by the transition into the CDW ground state, but their relative amplitude is different in the different points of the Brillouin zone, thus revealing a strong wave vector dependent electron-phonon coupling. Unfortunately, we did not succeed in observing the Amplitude Mode related to the CDW state. We expect this to be due to the relatively low value of the the critical fluence responsible for melting the CDW. We found that below that fluence, the experimental signal to noise ratio is poor preventing us from observing coherent oscillations.

LACUS and FERMI, at FERMI: “Element-selective vibrational spectroscopy of Fe₂S₂Cl₄ films by impulsive stimulated Resonant Inelastic X-ray Scattering at the Fe M_{2,3} and Cl L_{2,3} edges with chirped detection”

Sending Institution: Lausanne Centre for Ultrafast Science, Switzerland

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

Principal Investigator: Oliviero Cannelli

Achievements: We propose a proof-of-principle stimulated implementation of resonant inelastic X-ray scattering (RIXS) to measure element-selective low-frequency vibrational modes in the time-domain. The method relies on a free electron laser (FEL)-pump/near infrared-probe scheme which circumvents the energy resolution limitations of conventional frequency-domain vibrational RIXS. Coherent oscillations are impulsively stimulated in Fe₂S₂Cl₄ thin films by ultrashort FEL pulses tuned in resonance with the Fe M_{2,3}-edge (55 eV) and Cl L_{2,3}-edge (200 eV). The modulation of the system’s reflectivity is probed as a function of time by using temporally-chirped and energy-dispersed 795 nm pulses in reflection mode. The vibrational frequencies are retrieved by Fourier transform of the coherent time-domain signal. The proposed technique will combine the advantages of vibrational spectroscopy with the element-selectivity of resonant X-ray techniques, demonstrating the possibility of measuring specific low-frequency modes in molecular complexes of biological relevance. Furthermore, we will demonstrate the tremendous improvement in the acquisition speed of a chirped-detection over conventional time scans, enabling single-shot detection of the time traces and minimizing the noise caused by the shot-to-shot fluctuations of the FEL.

In this proof-of-principle experiment we demonstrated the feasibility of the proposed technique (stimulated RIXS) on a model system (Tellurium single crystals). We measured coherent oscillations in the time- domain using energy-dispersed optical light and further proved the advantages of the chirped-detection, which allowed to drastically reduced the acquisition times of the experiment. Thanks to this strategy, we could systematically characterize the response of the system as a function of the FEL pump excitation fluence and photon energy. The preparation days prior to the beamtime were crucial for the success of the experiment, since they enabled setting up the acquisition scheme and benchmarking it with preliminary all-optical measurements. The novelty of both method and acquisition strategy of our experiment required investing most of the beamtime in a full characterization of the model system. Obtaining convincing results on Tellurium prevented extending the measurements to the originally proposed system (Fe₂S₂Cl₄ thin films). However, our promising results pave the way for successful experimental campaigns on novel systems.



MBI and FERMI, at FERMI: “Direct detection of magnetic fluctuations in high-temperature 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

Principal Investigator: Bastian Pfau

Achievements: Femtosecond laser excitation of a ferromagnetic multilayer can create an extended topological phase comprising many skyrmions. The formation of this phase, proceeding on a sub-ns timescale, is mediated by a transient topological fluctuation state. This high-temperature state is characterized by strong spin fluctuations from which short-range order emerges during cool-down, leading to the formation of skyrmion nuclei. Here, we propose directly detecting these spin fluctuations using coherent resonant small-angle scattering and a split-pulse correlation technique. Our experiment will provide fundamental insight into the physics of ultrafast magnetic fluctuations and elucidate their role in the dynamics of the topological phase transition. The proposal is a continuation of a previous experiment that had to be performed under unsuitable conditions due to a severely damaged x-ray detector.

The goal of the experiment was to directly detect the spin fluctuations in a ferromagnet in the so-called fluctuation state after photo-excitation. It has been proposed that this fluctuation phase plays a crucial role in forming a topological skyrmion phase. Unlike previous experiments detecting (average) in-plane magnetic ordering based on time-resolved (incoherent) small-angle scattering, detecting temporal fluctuations requires coherent scattering. A suitable photon correlation technique to measure the decorrelation of the coherent speckle pattern at ultrafast timescales is based on exposures with two temporally separated FEL pulses.

In our beamtime, we established three technical prerequisites for this technique: (i) synchronization between double-pulse FEL probe, IR excitation, detector readout and magnetic field toggling, albeit only at 16 Hz, (ii) optimized spatial overlap of FEL beams on sample and speckle patterns on the detector, and (iii) single-shot acquisition of speckle patterns with sufficient signal. These achievements resulted in recording a fully time-resolved dataset for correlation analysis. This includes a variation in the time delay between the IR pump and double-pulse FEL probe as well as a variation in the temporal separation of the two FEL pulses. However, time constraints and technical difficulties only allowed for a limited amount of data. A follow-up study building on these achievements would be beneficial for a conclusive scientific result.

CLF at CELIA: “Terahertz (THz) production from laser-driven discharge pulses in wire targets” CELIA28627

Sending Institution: Central Laser Facility, Rutherford Appleton Laboratory, STFC, Oxfordshire, United Kingdom

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

Principal Investigator: Kirill Fedorov

Achievements: In recent years it has been shown that laser-plasma interactions can efficiently generate high intensity THz radiation via several mechanisms: sheath radiation, bremsstrahlung-like radiation, coherent transition radiation and antenna radiation from laser-driven wires. Recently, it has been demonstrated that radiation from laser-driven wires can reach the energy-to-THz conversion efficiency of 0.5%, although the THz emission mechanism has not yet been confirmed. Based on the existing literature and our own experimental work, we expect that wire material, wire shape, laser contrast and laser pulse duration may impact the spectral intensity, polarisation and angular distribution of THz radiation. We would like to explore the origin of long-pulse THz radiation from unstructured wire targets (to ensure a minimal impact on the dispersion and characterisation of the pulse) with full resolution of the discharge pulse length. We would also



like to perform detailed studies of emitted spectra by using a multichannel calorimeter system to make single-shot spectral measurements.

At Eclipse IV, we wanted to measure THz emission from thin-wire targets using a multi-channel THz spectrometer. The laser was focused close to one tip of a 50um-thick Cu wire. By measuring the THz energy radiated from the other end of the wire, as well as its angular spectrum of emission and polarisation, we were able to identify likely THz generation mechanisms and extrapolate performance to different experimental scenarios. We also planned to correlate the THz energy with measurements of the target charge and current profile. Charge measurements were taken directly with an electron spectrometer and indirectly with measurements of GHz emission. Polarimetric measurement of the current profile was not possible due to time constraints. We successfully tested a multi-channel THz spectrometer. We took measurements of GHz radiation, x-rays and electron spectra as well. To help with target metrology, we built a high magnification, two-axis target alignment rig for CELIA. Analysis is ongoing, but we have reached the stage where we can begin drafting an article. We intend to publish the results by early next year.



Annex 2

Details on Task 3: Staff exchange

LLC – CLPU

Sending Institution: LLC

Hosting Institution: CLPU

Duration: 1 week

Participating staff: Anders Persson

Achievements: Dr. Anders Persson is a well known expert in CPA laser technology, with a long track-record of successful achievements and laser operations at LLC. The collaborative tasks that have been developed during this joined activity were:

- Checking high power laser pumps power supplies degradation problem: Anders helped CLPU with the capacitor degradation measurements and possible solutions to the problem. He has long experience in this kind of degradation and could propose helpful procedure for safe characterization of capacitors as well as possible replacement solutions.
- Checking misalignment high power laser compressor problem: Due to this problem, analysis of temporal behaviour all over the day to study temporal drift couldn't be achieved. Anders joined the CLPU staff in order to guess possible solutions.
- Discussion about beamlines reorganization projects at CLPU: CLPU showed the new beamline reorganization project and difficulties aroused in the way. Anders suggested possible solutions for programming beampointing stabilization since his program has been longer tested at LLC. This was a really helpful discussion in order to launch this programming development project at CLPU.
- Discussion about laser laboratory operation: CLPU has developed several user-friendly tools devoted to improve the information needed to run the laser facility. These web-based software applications as well as the data base developed in order to get a data dictionary and a fast step towards hdf5 information files was discussed.
- Besides all this, Anders offered a very nice seminar on past and future laser developments and research lines at LLC.

CLL – LACUS

Sending Institution: CLL

Hosting Institution: LACUS

Duration: 2 weeks

Participating staff: Amilcar Duque Prata

Achievements: During the staff-exchange, it was possible to get in touch with the different experimental techniques existing at LACUS and learn how to operate the equipment and setups. The focused technique during the Staff-Exchange period was transient absorption spectroscopy with pump at 266nm and probe in the UV. The pump and probe pulse generation methods were explained and discussed, using 20kHz lasers and a high harmonic generation setup. Various methods were explored for beam optimization and stabilization, as well as probe profile shaping. Different sampling setups were used, such as using a common quartz cuvette, or a flow cuvette linked to pump or syringe, and a liquid microjet setup. These sampling methods are relevant for future use in experiments at the Coimbra Laser Lab. I had the opportunity to follow hands-on the characterization of a compound, and understand how to overcome the difficulties that arise throughout the process.



During the staff-exchange I also had time to observe and/or discuss the implementation of 2D spectroscopy, time and angle-resolved photoelectron spectroscopy and X-ray transient absorption spectroscopy techniques.

FELIX – MBI

Sending Institution: FELIX

Hosting Institution: MBI

Duration: 2 weeks

Participating staff: Carl Davies

Achievements: The aim of the staff exchange was to transfer knowledge relating to high-harmonic-generation (HHG) lasers, with emphasis on using such a light source to probe element-specific magnetization dynamics induced by a pump laser. The receiving team at MBI are leading experts in the use of HHG for probing spin dynamics in alloys and more complex structures. At FELIX Laboratory, we have procured a HHG laser source, but lack prior hands-on experience.

The staff exchange was very successful. Over the course of five days, I gained a wealth of insight and experience in to how to e.g. align a HHG laser, optimize pump-probe overlap, analyze the intensity of selected harmonics etc. In particular, I was very impressed by the automation of such experiments. Before the visit, I did not appreciate the importance of using various motorized translation and rotation stages to optimize the measured signals, which are obtained in-vacuum. This level of control allows experiments to be performed over extended periods of time, which is critical since the measurements must often be integrated over several hours. The team at Max Born Institute were very helpful in showing the technical aspects of the setup, and explaining how they overcame different problems while constructing it.

As a result of the staff exchange, I have begun building a setup involving the HHG laser at FELIX. In parallel, we are working to develop software which will control different elements inside the vacuum chambers. We hope to begin our first test measurements in the coming weeks. The experience I have gained as part of this staff exchange has already boosted the development of the HHG-associated setup at FELIX.

CLPU, CELIA – PALS

Sending Institutions: CLPU, CELIA

Hosting Institution: PALS

Duration: 2 weeks

Participating staff: Michael Ehret, Philip Bradford

Achievements: This Laserlab Staff Exchange was conceived in order to develop a high-performance current and voltage probe for use on a range of high power laser facilities. The idea was to develop a previous probe design by J. Cikhardt (CTU) that can be placed unobtrusively beneath the laser target, as part of the target mounting system, where it records the passage of the discharge current as it propagates to ground. Similar to a Rogowski coil or B-dot antenna, Cikhardt's probe measures the laser current via electromagnetic induction, but is ingeniously designed to make the probe resistant to radio-frequency noise, ionising radiation and electrical breakdown. The project was organized in two stages: first, the existing probe RL frequency response was increased and second, an experiment was conducted on the PALS laser to test probe performance under a range of conditions. New probes – one for CLPU and one for CELIA - were designed and fabricated in a collaborative effort, then transported to the PALS laser facility where they could be calibrated.



Over the course of the experiment at PALS, M. Ehret and P. Bradford learned how to operate inductive current probes under the supervision of J. Cikhardt, who is an electrical and plasma diagnostics expert. They developed skills for measuring multi-kA return currents in target mounting systems and gained hands-on experience with a range of target charging monitors. The collaboration has proved useful to CTU and PALS, because it has explained why the probe appears to operate in two different regimes - derivative and integrating – depending on target and laser conditions. It has also produced a more versatile probe that will produce better current measurements for future experiments.

The team is now involved in developing a high repetition-rate current diagnostic for permanent use on the fs-duration VEGA-3 laser, as well as a platform suitable for ns-duration long-pulse laser systems such as Vulcan in the UK. CLPU and CELIA are in the process of procuring cables and high voltage attenuators to complete their current measurement systems. The construction of three new current probes, as well as the training received by CLPU and CELIA researchers, will enable the Laserlab Expert Groups to measure laser-driven currents easily at several major international laser facilities.

ENEA – CLPU

Sending Institution: ENEA

Hosting Institution: CLPU

Duration: 2 weeks

Participating staff: Massimiliano Scisciò, Pierluigi Andreoli

Achievements: The exchange aimed at acquiring know-how and expertise on two specific diagnostic instruments that are typically involved in experiments of high-power laser-matter interaction: Radiochromic Film detector (RCF) and Kirkpatrick-Baez microscope (KBM).

RCF detectors: These detectors are used in laser-plasma experiments for radiation and particle revelation. When irradiated with photons and/or particles, they change color according to the received dose: by performing a calibrated scan of the film, it is possible to retrieve the number of particles and/or photons that impinged the detector. During our exchange, we tested RCF detectors of the type HDv2, manufactured by Garfchromic. These provide a sensitivity also to low-energy particles (keV range), due to their unfiltered active layer. We implemented this type of RCF film during test shots of the Vega III laser on a metallic solid target, with the aim of revealing laser-generated protons and heavy ions. As shown in Fig. 1, the RCF film was inserted in Thomson spectrometer, serving as a passive detector. After the exposition, we performed a scan of the irradiated detector with a scanner EPSON Perfection V750 PRO available at the CLPU facility. The retrieved image, however, did not show any evident trace of particles (see Fig. 2 where the scanned image is reported). This is likely due to the low number of particles that entered the spectrometer, which has a small acceptance angle and intercepts only a small part of the laser-generated particles. Summarizing, we successfully implemented RCF detectors during test shots of Vega III. The configuration we tested can be used in future experiments and we learned about the limitations of this detector. The gained know-how will allow us implementing this diagnostic on the ABC laser, also in hindsight of hosting external users.

Kirkpatrick-Baez microscope:

This device is used for x-ray imaging in laser-plasma experiment. It uses curved, high-Z metallic coated mirrors that focus the laser-plasma generated x-ray beam, allowing to obtain a microscopic image of the x-ray emission point. Such a device has been developed at the CLPU facility (see Fig. 3) and tested on the Vega II laser. It features two independent benders that steer the mirrors, driven by nm-precision piezo-electric motors. The collected radiation can be then monitored by a x-ray CCD camera (the model Greateyes GE1024256 is available at CLPU, pixel size 26 micrometer). This diagnostic is particularly useful for imaging the laser-



target interaction point in TNSA and p-11B fusion experiments, both of interest of ENEA and CLPU. From the CLPU scientists we learned about the capabilities and the limitations of this diagnostic. We discussed the possible implementation of this diagnostic tool in future experimental campaigns and the gained know-how will possibly allow us developing a KBM to be implemented at the ABC laser facility, adding an important diagnostic tool for internal and external users.

CLF – POLIMI

Sending Institution: CLF

Hosting Institution: POLIMI

Duration: 2 weeks

Participating staff: Robert Lees

Achievements:

- Knowledge of CUSBO techniques for potential collaborations between optical trapping and light sheet microscopy
- Hands-on experience with light sheet microscopy optics, building a microscope across 2-3 days
- Experience and knowledge of image analysis techniques from creators of Napari plugins at CUSBO
- Imaging of zebrafish, plant and organoid samples on two custom lightsheet microscopes at CUSBO, data collected and taken home for analysis examples
- Characterisation of custom light sheet microscopes at CUSBO (laser light width, depth, alignment), essential skill for characterising lightsheet at CLF
- Networking with between 10 and 20 academics at CUSBO over the 2 weeks in the fields of biomedical imaging and spectroscopy

CLF – IPHT

Sending Institution: CLF

Hosting Institution: IPHT

Duration: 1 week

Participating staff: Lin Wang

Achievements: Lin Wang (LW) from CLF has completed his visit to the world-leading research group headed by Prof. Rainer Heintzmann (RH) at Leibniz-IPHT. The new skills gained by LW from this staff exchange activity promise significant boost of CLF's productivity in super-resolution microscopy offered to academic and industrial users from across the Europe. The output from this visit is summarised as follows,

(1) LW gained access to the custom-designed software package for Structured Illumination Microscopy (SIM) image processing. The MATLAB-based software provides a palette of diagnostic tools for multi-parametre optimisation in super-resolution image reconstruction, which is not available in the commercially available softwares used in CLF. Following the tutorials conveyed by RH, LW is on the path to apply the software in reducing SIM imaging artifacts from the raw data acquired from ZEISS Elyra microscopy system in CLF;

(2) LW gained access to the software GenericDeconvolution developed by RH. This software offers powerful generic deconvolution on microscopy data from multiple imaging modalities, such as wide-field, confocal, two-photon, light sheet and STED microscopy. RH delivered



comprehensive tutorials and demonstrations to LW, using the software to enhance image resolution and generate simulation data for benchmarking;

(3) RH demonstrated how to use View5D plugin in open-source Fiji software package. The skills LW obtained included, but not limited to, navigation through up to 5 dimensional (XYZ coordinates, colors, and spectral curves and a time slider) datasets, semi-automatic tracking and scattergrams;

(4) RH demonstrated a bench-top SIM system. The in-depth diagnostic structured illumination pattern optimisation, e.g. laser beam polarisation adjustment, deepened LW's understanding on SIM's working principle and practical know-how;

(5) A novel Structured Illumination Microscopy, namely ROI-SIM, is developed in RH's lab to enable super-resolution imaging of thick biological samples. LW shadowed RH's bench work and upskilled in many ways, including Python programming for structured illumination pattern generation, Labview programming for acousto-optic modulator (AOM)/liquid crystal on silicon (LCOS) spatial light modulator/scientific camera controls, optical alignment and polarisation optimisation in a SIM system, and camera display troubleshooting;

(6) LW and RH also paid a visit to Carl Zeiss Microscopy GmbH at Jena, and had a productive meeting with Zeiss Research Microscopy Solutions team, covering a wide range of topics ranging from strengths and limitations of Zeiss research microscopes to challenges in translating technologies from bench to market. We also toured some microscope labs where the Zeiss team demonstrated a few cutting-edge microscopes, e.g. lattice light sheet, in action. The visit paved the way for a wider collaboration with industrial partners.

GSI – ENEA

Sending Institution: GSI

Hosting Institution: ENEA

Duration: 2 weeks

Participating staff: Olga Rosmej, Mikhail Gyrdymov

Achievements:

The aim of the staff exchange was to gain deeper insights into the complex diagnostic setup established on the ABC laser and to transfer this knowledge to the plasma physics group at the GSI. The ABC diagnostic setup includes an optical streak, shadow photography, interferometry, measurements of transmitted and reflected plasma laser light.

In the course of the experimental campaign on the ENEA-ABC laser, the properties of plasma generated by the interaction of a nanosecond ABC laser pulse with low-density polymer foams with a density of 2–3 mg/cm³ and submillimeter thicknesses were studied. To obtain time-dependent information about the speed of thermal waves inside the foam layer during the action of a laser pulse, the speed of plasma expansion, the distribution of plasma density and temperature, etc., an optical streak, shadowgraphy, interferometry, measurements of transmitted and reflected from plasma laser light were used. The required data is currently being evaluated and discussed with the theoretical teams providing HD simulations.

The team of the ABC Laser were very helpful in showing the technical aspects of different diagnostics and explaining how they overcame various design issues. In summary, the stay at the ABC laser in the frame of the staff exchange activity aiming at training was very successful and led to closer cooperation between the ABC team and the plasma physics groups at GSI.

MUT – FERMI

Sending Institution: MUT



Hosting Institution: FERMI

Duration: 3 weeks

Participating staff: Martyna Wardzinska

Achievements: In June 2023, I took part in a staff exchange as part of the Laserlab Europe consortium project. I worked for three weeks at the Elettra Sincrotrone Trieste facility. I joined the PADReS team, which deals with the preparation of the photon beam from the FERMI free-electron laser for experiments performed at the endstations located in the experimental hall. The PADReS team members introduced me to each of the six endstations used to perform the various experiments. In addition, they explained me the operation of all the instruments in the line, including the Kirkpatrick-Baez Active Optical System (KAOS) and the optical device called AC/DC - Auto Correlator/Delay Creator, which I found particularly interesting. In addition, I had meetings with scientists almost every day:

- Physicists working in the 'Control Room', where the FEL parameters in the accelerators and undulators are verified and controlled.
- The X-ray Optics Group Leader, who showed me several laboratories equipped with modern metrology devices.
- The staff member managing one of the Elettra synchrotron's end station, who explained me in detail Elettra's operation and the research areas they deal with.
- A member of the PADReS team introduced me to the Oasys computer programme in which optical simulations can be performed.

For three weeks, I participated in the preparation of the beamlines for three different experiments carried out at three different endstations.

To sum up:

- 1) I established a research collaboration with the PADReS team working on the FERMI free-electron laser. I was offered the opportunity to join their team in a post-doc position after completing my PhD.
- 2) Since I was involved in the design of the VUV line of the Polish Free Electron Laser for over two years. Now, having worked on this type of device for three weeks, I have a lot more knowledge on the subject and my experience may prove useful in the further stages of line design.
- 3) The Oasys programme is similar to the RAY-UI programme I use for ray-tracing simulations in optical systems. It is an additional tool that may prove useful in the analyses I will include in my dissertation.
- 4) I offered to share my knowledge and prepare an exchange report that I could present at an institute seminar at my facility.

CLUR – CUSBO

Sending Institution: CLUR

Hosting Institution: CUSBO

Duration: 2 weeks

Participating staff: Pedro Recio Ibáñez

Achievements: During the two weeks exchange, the candidate learned and practiced with several students and researchers working in the laboratory in different setups that the CUSBO research group has to perform their experiments. The candidate learned the know-how related to these experiments and the different parts and techniques required to perform them.

In particular, the candidate helped align hollow-core-fibers (HCF) compressors in the several applications the hosting facility uses, as well as the conditions (length, inside diameter,



pressure, and gas) required for each application. He gained experience with these apparatus and learned the best conditions for different applications. Among the applications in which CUSBO used the HCFs, generating few-cycle ultrashort pulses in the ultraviolet (UV) was the most interesting for the candidate and the sending facility (CLUR). Since the hosting facility has been able to mount a setup to use the technique and they are implementing it in one of the experiments, the candidate was able to learn how to produce the few-cycle UV pulses, so he will be able to implement it in the laboratory of the CLUR research laboratory in Madrid.

In addition, the candidate could participate in several experiments performed with a time-compensated monochromator. Thanks to the participation in the experiments, the candidate was able to learn and understand the monochromator several parts and gain experience in performing experiments with this system. This experience will help the sending facility to implement a monochromator in their laboratory to perform experiments with a single harmonic.

Finally, the candidate also had the opportunity to see the performance of the newest laser that the hosting facility bought recently. This was a great opportunity since a similar laser will soon arrive at the sending facility. The knowledge gained on how and under which conditions the laser works at its best conditions will make it easier to learn how to operate and handle the new laser in the CLUR. On the other hand, the candidate was able to help find new and better ways for the hosting facility to dispose of the residual molecules and fragments generated in the reaction chambers. The candidate also helped install a modification in the molecular gas line that inserts the measuring molecules inside the chamber so a carrier gas could be used if required.

CUSBO – ICFO

Sending Institution: CUSBO

Hosting Institution: ICFO

Duration: 2 weeks

Participating staff: Cristian Manzoni, Alessandro Baserga

Achievements: Development and Integration of the NOPA

The goal of the exchange is to implement a NOPA for the generation of sub-10 fs pulses in the visible range. The pulses will be employed to perform Attosecond Transient Absorption soft X-ray (SXR) Spectroscopy (ATAS). The development required a sequence of actions that have been taken by Cristian Manzoni and Alessandro Baserga during the visits at ICFO, as detailed in the following:

First stage of NOPA and FROG:

We implemented the first stage of the NOPA system. The NOPA was powered by a fraction of the fundamental light at 800 nm from a Ti:sapphire laser. To this aim, we optimized the laser source and then implemented the second-harmonic and white light generation stages. After synchronization, we obtained amplification in a 1-mm BBO. The NOPA delivered broadband visible pulses with energy of 3.5 μ J, by pumping with pulses with 160 μ J at 800 nm. The spectrum corresponds to transform-limited pulses with 5.8fs.

To characterize the pulses, we developed a setup for NOPA pulse metrology. Addressing the challenge of the NOPA's broad tunability, we implemented a Frequency Resolved Optical Gating (FROG) system. Initial tests were conducted using second-harmonic FROG; the system easily adapts to transient-grating FROG, if necessary, particularly for UV pulse measurements or to mitigate dispersion issues.

NOPA second stage and pulse characterization:

We implemented the second stage of the NOPA. This required finding the splitting of the fundamental light into the first and second stages, and matching the modes of pump and signal



beams. The duration of the pump beam at 800nm, measured with the FROG, is 55.3 fs. We obtained the following pulse energies:

First stage: $E < 3\mu\text{J}$, 5.8fs (transform limit duration), 18.6 fs (measured)

Second Stage: $E = 8.9\ \mu\text{J}$, 6.8 fs (transform limit duration)

The second stage amplifies the pulse energy by a factor of 3, but also reduces the bandwidth.

Optimization of the NOPA system and coupling into the chamber:

One of the goals of this visit is to check whether the broader pulses from first stage have sufficient peak intensity to perform the experiment. This is obtained if the pulses have a good (ideally, Gaussian) beam profile, which ensures the best focusing of the beam. We used the light from the first NOPA stage (1.6 μJ energy), and excellent spatial profile.

We adjusted the divergence properties of the NOPA beam; the size at the sample point was 90-100 μm , and the pulse energy was 0.4 μJ . The corresponding fluence is 2.83 mJ/cm^2 , which is more than sufficient for the ATAS experiment. This demonstrates that one NOPA stage is sufficient to drive the experiment and to support Laserlab-Europe's experimental access offerings. To achieve the ultrafast temporal resolution necessary for ATAS, chirped mirrors were employed to compress the NOPA pulses to a transform-limited duration of under 10 femtoseconds.

IST – CLF

Sending Institution: IST

Hosting Institution: CLF

Duration: 2 weeks

Participating staff: Gonalo Alexandre Lu s Vaz

Achievements: As a result of this staff exchange the participant gained invaluable knowledge on running a user focused laser facility, and also on the state-of-the-art experiments being performed at the Rutherford Appleton Laboratory (RAL).

The L2I laboratory in Lisbon has historically been a academic facility which served mostly members of the University of Lisbon. With the integration of the laboratory into the Portuguese National Roadmap of Research Infrastructures we expect to receive a significant increase in external users, hence the dire need for the know-how of running a user facility. RAL as one of the largest laser facilities on the globe has a long history of serving users. During this stay the participant was introduced to:

-How Artemis efficiently and effectively trains users of different backgrounds to perform experiments with high powered lasers. In particular how to properly introduce all the risks and safety protocols, with highlight on the need to not only update these protocols, but also mandate a refreshment of this training, even to long time users.

-The vitality of defining a time usage and assure the allocation of human and material resources to assure that maintenance works do not interfere with user experiments. Including the establishment of a priority list for this allocation, encompassing the needs of stakeholders, users and the scientific team. Additionally, the participant was introduced to the differences of 24h and 8h facilities, in particular on how they account for UP, DOWN and EXTRA time, and what is included into the users allocated time.

-The concept of Hierarchy of Controls which helps minimize the associated risk without excluding users from the experiment. Prioritizing engineering as it is the most viable way to isolate users from the hazards by introducing remote controls and diagnostics.



-The need to closely interact with users before and after the experiments to include their feedback in current timeslots and to design future setups to account for their future needs. With special attention to avoid scope creeps.

During this stay the participant was also able to observe the experimental facilities of Artemis in involving photon emission and photon electron time-of-flight experiments. Including a description of the available laser systems, amplification, compression and high harmonic generation stages as well as diagnostics. With particular focus on all the available control and diagnostic systems as well as software interfaces developed as part of the Hierarchy of Controls. Additionally, the participant observed the practical application of the concepts underline during a user experiment which was in effect during this exchange.

Finally, the participant was able to briefly visit other laser facilities of RAL including Ultra's Raman scattering spectroscopy experiment and a visit to Vulcan which is being dismantled for the upcoming upgrades related to the Vulcan 20-20 project.

ULLC – CUSBO

Sending Institution: ULLC

Hosting Institution: CUSBO

Duration: 2 weeks

Participating staff: Vanesa Lukinsone

Achievements: The collaborative execution of Time-Of-Flight experiments was one of the exchange goals. The major objective was to exchange knowledge and expertise in this area in order to conduct experiments and collaborate. A collaborative experiment including a liquid and solid phantom, different concentrations of nigrosin, and joint discussions of the outcome were conducted in the CUSBO laboratory.

Determining the absorption at various concentrations of Nigrosin within the 600–1100 nm range was the experiment's main focus. The experiment was carried out on a TCSPC system using the TOF method. Through collaboration, knowledge was acquired about forming a solid and liquid phantom and getting it ready for examination. Practical knowledge of the Time Domain measurements setup in the CUSBO laboratory was acquired during the measurements. As well data processing utilising the created program in CUSBO.

Conclusions:

1. Experience in creating phantoms was gained.
2. Theoretical and practical knowledge of the experimental setup for measuring the Time-Of-Flight signal at the Politecnico de Milano (CUSBO).
3. Gained signal processing skills utilizing created and developed methods and programs in CUSBO.

CLF – CLPU

Sending Institution: CLF

Hosting Institution: CLPU

Duration: 2 weeks

Participating staff: Samuel Buck

Achievements: Goal: use of a novel diagnostic developed at the CLF to test performance of the VEGA beamlines. Share ideas on petawatt-class laser diagnostics.



Achieved: Angular dispersion of the VEGA system was measured in 17 locations to produce a summary of the laser performance for both VEGA 2 and VEGA 3 beamlines, with most attention to the post-compressor output(s). This gives insight on how and where to focus laser improvement - specifically towards experimental benefits, as discovered from previous experiments at the CLF.

The exchange of knowledge for short pulse/broadband diagnostic techniques enables both facilities to better characterise short pulses. General laser layout and experience/knowledge was also exchanged.

The insight from this work gives the CLF better data on petawatt-class laser characteristics with which to aid ongoing design work, and for the CLPU, possible future collaboration on implementing components and/or changes to address the issues found..

CLF – CLPU

Sending Institution: CLF

Hosting Institution: CLPU

Duration: 2 weeks

Participating staff: Enrique García García

Achievements: The achievements of the exchange were better than expected. Enrique had the opportunity to join the CLF laser team to see VULCAN and starting EPAC facilities. He was joining the group of people checking OPCPA amplifiers and got some training on this, what was unexpected but great.

He travelled with part of the necessary equipment from Spain to install the temporal characterization setup that CLPU is now testing together with the University of Salamanca. Enrique had the opportunity to check the temporal prototype in CLF facility retrieving near field beam profiles for different wavelengths and the results are still under analysis. On the other hand, Enrique also had the opportunity to follow Sam during his staff exchange at CLPU as host facility and could also test CLF tilt measurement device. We must say that we are definitely very happy with having the opportunity to join problems and solutions and the with the results of this exchange.

CLPU – STRATH

Sending Institution: CLPU

osting Institution: STRATH

Duration: 2 weeks

Participating staff: Jose Antonio Pérez Hernández

Achievements: Dr. Jose Antonio Pérez-Hernández participated in a staff exchange for 13 days at the SCAPA facility (Scottish Centre for the Application of Plasma-based Accelerators), Strathclyde University, Glasgow, Scotland, United Kingdom, working with Prof. Dino Jaroszynski's research group. During this stay, Dr. Pérez- Hernández participated in an experimental campaign for radioisotope production using laser wakefield accelerators under the supervision of Dr. Mark Wiggins, a senior scientist at SCAPA. Dr. Pérez-Hernández participated in mounting the experimental set-up in Beamline A3, which utilises of one of the lines of SCAPA 350 TW laser, and in the subsequent acquiring of data for the experiment. He was trained on managing a high energy electron spectrometer, optimization the energy of the electron beam for irradiating the convertor and target, positioning the target at different angles, irradiation of different kind of targets for producing different radioisotopes and the subsequent data acquisition and processing. He also learned the techniques used for laser beam and electron beam alignment used at SCAPA.



The techniques acquired during this stay are in line with part of the research lines at CLPU, where radioisotope production is also being carried out using the VEGA laser system. In addition, due to the similarity between one of the lines of the VEGA system (200 TW VEGA 2 line, 30 fs) and the beamlines at SCAPA laser (26 fs 350TW) used during this stay, the techniques and knowledge achieved will be of mutual benefit to both facilities

CLPU – ICFO

Sending Institution: CLPU

Hosting Institution: ICFO

Duration: 1 week

Participating staff: Cruz Méndez

Achievements: Throughout the week, there were opportunities to share knowledge and experiences between both laboratory facilities. The visit offered a comprehensive understanding of various technical challenges and potential collaborative avenues in the field of high-power laser technology. The opportunity to attend a thesis defense within Jens Biegert's group was particularly insightful. Discussions following the defense with some members of the thesis tribunal were very useful shedding light on how other European facilities address key challenges such as thermal grating stability and pump-probe jitter setups for beam combining. The staff involved in the exchange engaged directly with different working teams in the lab, actively discussing their projects focused on the improvement, update and utilization of the different laser systems. One key area of focus was the table-top high-energy 7 microns OPCPA system. During the exchange, the staff received a thorough explanation of the system's main components and participated in hands-on work to realign the regen amplifier of this system. This experience was very important for identifying and understanding additional challenges posed by operating in this wavelength regime, such as alignment difficulties, availability of compatible components in market and complexities of pumping technologies. Potential solutions and strategies to address these challenges were also discussed. In addition to this system, the group operates two other OPCPA systems. The visiting staff was introduced to the primary components of both systems and had the opportunity to join laboratory activities aimed at addressing specific technical issues. For instance, efforts to correct the behavior of a cryo-cooling component were observed, also cryo-cooling need for a regen amplifier was checked alongside discussions about plans to integrate a new pump laser into one of the systems in order to enhance the setup's capabilities for imaging molecular structures.

There was an opportunity for a detailed presentation outlining the equipment, projects and planned upgrades for VEGA laser system. These discussions provided an excellent platform to explain the main aspects of VEGA's laser technology and its various subsystems. Specific improvements, such as the delay line between VEGA 2 and VEGA 3 and the possibility of offering uncompressed output for VEGA 3 were also presented. Discussions also centered on enhancing VEGA's position within the European high-power laser framework. Several promising ideas for future collaboration emerged, in particular, the potential to expand VEGA infrastructure with an additional output at a wavelength greater than 800 nm. This initiative would join Jens' group expertise in longer wavelengths with CLPU's capacity for system expansion and will be reviewed in following months.

CLPU – CLF

Sending Institution: CLPU

Hosting Institution: CLF

Duration: 2 weeks

Participating staff: Iuliana-Mariana Vladisavlevici, Michael Ehret



Achievements: Iuliana-Mariana Vladisavlevici (IV) and Michael Ehret (ME) helped Dr H Ahmed and Philip Bradford with target alignment and multi-pinhole Thomson Parabola data acquisition in Gemini TA3. The TA1 beam was brought into TA2 as a probe and a further ~18.5m delay added to overlap it with the TA2 pump beam. IV was given a tour of the Gemini laser system and each target area.

ME and IV delivered seminars to the department entitled "Currents from relativistic laser interaction as metrology for system stability of HRR laser secondary sources" and "Spatial characterization of debris ejection from the interaction of a tightly focused PW-laser pulse with metal targets". The ChoCoLaTv2 target charging code was extended to account for a return current. This will allow us to model target charging induced by lasers with pulse durations exceeding a few ps. Hot electron temperature scalings suitable for integration into the code were also discussed.

ME visited RAL Space to conduct Bruker terahertz transmission tests for different optical components (THz bandpass filters, HRFZ-Si windows, splitters). These will be important for future terahertz energy experiments at Gemini and EPAC, as well as for quantifying previous measurements.

ME and Kirill Fedorov discussed a new THz bandpass filter design for future experiments on EPAC. The theory of how to build an accurate terahertz spectrum using filters with non-zero bandwidth was also explored.

ME met with Dr H Ahmed to discuss modelling of laser-driven discharge pulses.

Future Direction:

Following her work on the Gemini probe beam, IV is now ready to develop a combined interferometry-shadowgraphy system for CLPU. Following the seminars and subsequent exchanges with CLF target fabrication staff, we have identified debris characterisation a topic of collaboration between the CLF and CLPU. A follow-up meeting is planned for late November with S. Astbury, D. Haddock, N. Booth, C. Spindloe and D. Carroll in order to discuss a possible experimental proposal at HiLASE.

S. Astbury and D. Haddock have since conducted measurements of debris thickness, composition and spatial distribution on witness plates used in a prior experimental campaign on ELI-NP. Plate roughness measurements were conducted using a white light interferometer (3D Optical Profilometer Bruker ContourX-100) and a Dektak Pro Stylus Profilometer, while elemental analysis was performed with a Pemtron PS-230AL Scanning Electron Microscope (SEM), fitted with a Bruker QX2 EDX system. IV and ME have incorporated these findings into a paper that has now been submitted to HPLSE.

The terahertz Bruker test results will be used to enrich a forthcoming joint CLF-CLPU publication on terahertz radiation emitted during laser-solid interactions at ELI-NP and CELIA. The extension to the ChoCoLaTv2 code will be used in an upcoming publication describing EMP measurements at the PALS facility, as well as in future modelling of EMP at Vulcan 20-20.

CELIA – CLF

Sending Institution: CELIA

Hosting Institution: CLF

Duration: 1 week

Participating staff: Nikita Fedorov

Achievements: The primary goal of this staff exchange was to collaborate on the update and enhancement of several advanced plasma diagnostics, including shadowgraphy, Schlieren, and interferometry. This initiative aimed to advance the capabilities of both facilities in capturing



high-quality plasma diagnostics to support ongoing research in wakefield electrons acceleration.

Summary of Activities: During the five-day exchange period, we worked collaboratively to review, update plasma diagnostic equipment. The activities included hands-on updates, testing, and verification of performance in the following diagnostics:

1. Shadowgraphy:

- Updated components of delay line and alignment techniques to improve time resolution and contrast for better visualization of plasma boundary structures.

2. Schlieren Imaging:

- Adjusted optical setups by addition a focal spot block to switch from shadowgraphy, allowing finer detection of density gradients within gas in cell.
- Improved synchronization with laser systems and gas valve to ensure optimal timing for cell's filling time.

3. Interferometry:

- Enhanced calibration procedures for interferometers to improve accuracy in measuring plasma density variations.
- Implemented data processing upgrades to support more precise and high-frequency sampling, enabling more detailed analysis of density profiles, using Fourier and Abel transform.

Outcomes: We discussed potential improvements for the CELIA facility, such as additional diagnostics for the laser beam on each shot, including pulse duration, wavefront measurements, and focal spot analysis. We also reviewed different gas cell geometries, pumping systems, and radiation protection measures for both low- and high-repetition-rate laser operations.

Future Directions: This successful collaboration has laid the groundwork for potential follow-up exchanges and joint research projects. Future initiatives may include collaborative experiments on wakefield electron acceleration, betatron emission, and terahertz radiation generation.

ENEA – GSI

Sending Institution: ENEA

Hosting Institution: GSI

Duration: 2 weeks

Participating staff: Mattia Cipriani, Massimiliano Sciscio

Achievements: Objective of this exchange was to acquire know-how on diagnostics operating at the PHELIX laser facility, for X-ray, gamma and particles, with a focus on TLD (ThermoLuminescent Dosimeters) for gamma rays and neutron diagnostics, and Bonner spheres and bubble detectors, for neutron diagnostics.

Thermoluminescent Dosimeters

The detectors used were constituted by lithium fluoride. When ionizing radiation interacts with the lattice of the material, electrons are excited to higher energy state and trapped in metastable states. When the material is heated, luminescence is produced revealing the dose. At GSI we could be acquainted with lithium fluoride TLD during test shots at the PHELIX facility. The TLDs were mounted on metallic frames, with four slots hosting a single TLD each (see Fig. 1). One kind of frame had four TLD all of them insensitive to neutrons, while in the other kind two out of four slots contained TLD sensitive to neutrons. The comparison between them allows obtaining information on the neutron contribution to the overall dose. The TLD were



placed in special stack-containers, with shields of different thicknesses, for measuring the dose from photons and/or neutrons of different energy (see Fig. 2). In some shots, these detectors were coupled with Imaging Plates (IPs). We gained a good experience with these detectors, which will allow us to employ them in future experimental campaigns.

Bubble detectors

Bubble detectors are constituted by a clear plastic tube filled with a gel polymer. When energetic neutrons collide with the polymer, the latter gets superheated, creating a bubble in the gel (see Fig. 3). The bubbles can be counted after the interaction. The detectors are calibrated by the manufacturer and a formula relates the number of obtained bubbles to the total number of neutrons emitted by the source. During the test shots at PHELIX, bubble detectors were placed in different locations around the interaction chamber. We learned about general principles concerning the positioning of these detectors, such as placing them behind protective layers/shields for avoiding the interaction with energetic protons and avoiding the proximity to metallic materials which might act as moderators. With the gained experience, we will be able to use these detectors successfully in our future campaigns when the detection of neutrons will be needed.

Bonner spheres

A Bonner sphere is constituted by a plastic material, able to moderate energetic neutrons. Inside the sphere, a material sensitive to neutrons is inserted for detection. In the case of the test shots at PHELIX in which we participated, the detectors were an ND IP and/or TLDs. If spheres of different sizes are used simultaneously, spectroscopic information on the neutron emission can be obtained. Three spheres of different radii were fielded (see Fig. 4), during the test shots at PHELIX. We obtained important experience for utilizing them in future campaigns

MUT – LLC

Sending Institution: MUT

Hosting Institution: LLC

Duration: 2 days

Participating staff: Henryk Fiedorowicz, Andrzej Bartnik, Tomasz Fok, Lukasz Wegrzynski

Achievements: The purpose of the MUT-IOE team's visit to the LLC center as part of the Staff Exchange was to conduct scientific consultations related to the construction of a radiation source in the VUV spectral range, which is based on the generation of high-order harmonics (HHG) of femtosecond laser radiation. The source is currently being built by the MUT-IOE team as part of the PoIFEL project, financed by the European Commission and implemented at the National Center for Nuclear Research (NCBJ) in Otwock near Warsaw.

The LLC team is widely known for its very high competences in the field of HHG. In addition, a few years ago, this team built a radiation source based on HHG, the parameters of which meet the requirements specified for the source planned in the PoIFEL project. The LLC source uses the PHAROS femtosecond laser with the same parameters as the laser that will be used in the PoIFEL project. The laser allows for the generation of femtosecond pulses at a repetition rate in the range of several hundred kHz. In addition, due to specific requirements for the average power of the generated VUV radiation pulses, the use of a gas jet with a continuous high-pressure gas flow over time is being considered for the generation of harmonics in the PoIFEL source. Such a solution, which involves the need to solve various technical problems, is used in the case of the LLC source.

A one-day consultative visit to the LLC centre was organized by Cord Arnold. The visit began with a meeting of the MUT-IOE team with the LLC team dealing with HHG, after which they familiarized themselves with the HHG source system using the PHAROS laser and the details of its design. The MUT-IOE team members obtained a number of information that will be very useful during the



construction and installation of the source at NCBJ. They mainly concerned the parameters of the laser used in the source and the system for generating a continuous gas jet.

In the second part of the visit, the MUT-IOE team presented the project of the source being built at NCBJ. The discussion with the experts from LLC and their comments provided many valuable tips for the MUT-IOE team. The MUT-IOE team members met with the director of the LLC center, Per Eng-Johnsson, and also got to know other laser laboratories where research is conducted in the field of HHG and acceleration of charged particles with lasers.

The Staff Exchange visit of the MUT-IOE team to the LLC center should be considered very useful and successful.

ILC – VULRC

Sending Institution: ILC

Hosting Institution: VULRC

Duration: 2 weeks

Participating staff: Tomas Mitura

Achievements: During my stay, fabrication of microstructures by 2-photon photopolymerization using Femtika Laser Nanofactory was demonstrated by VULRC team and various phases of photoresist preparation and post-fabrication processes were observed.

In particular, a technical meeting was held where issues related to effect of overlapping lines printed using direct laser writing causing physical abnormalities were discussed. The cause was pinpointed and a solution based on material composition was suggested. Furthermore, some aspects of theory of photopolymerization were discussed, revealing a possible option to increase structural stability of printed structures without affecting the resolution. The differences in working with a solid epoxy-based photoresist and liquid resist were highlighted and discussed. A plan of fabricating identical structures on solid and liquid photoresist to experimentally observe the differences was formed.

On the other hand, during the collaborative visit the students at VULRC were shown a method how to optimize fabrication parameters. As a part of mutual discussion, ways to improve the post-fabrication development process were shared between the participants from past experiences. A presentation showcasing past and current projects of ILC SCSTI was given at the VULRC.

