LASERLAB-EUROPE

The Integrated Initiative of European Laser Research Infrastructures V

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Work package 3 – NA2 –Scientific and Technological Exchanges

Deliverable D3.4
Second and open joint JRA meeting

Lead Beneficiary: 1 – CNRS

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Project webpage: www.laserlab-europe.eu

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

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1 Introduction to Laserlab-Europe

Laserlab-Europe is the European consortium of major national laser research infrastructures, covering advanced laser science and applications in most domains of research and technology, with particular emphasis on areas with high industrial and social impact, such as bio- and nanophotonics, material analyses, biology and medicine.

Recently the field of advanced lasers has experienced remarkable advances and breakthroughs in laser technologies and novel applications. Laser technology is a key innovation driver for highly varied applications and products in many areas of modern society, thereby substantially contributing to economic growth. Through its strategic approach, Laserlab-Europe aims to strengthen Europe's leading position and competitiveness in this key area. It facilitates the coordination of laser research activities within the European Research Area by integrating major facilities in most European member states with a long-term perspective and providing concerted and efficient services to researchers in science and industry.

2 Objectives of the Joint JRA meetings

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.

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 final Joint JRA meeting was planned as open session specifically addressing external participants, e.g. from industry and medical communities.

3 Second and open Joint JRA meeting

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 preparation and the format of the meeting have been discussed by a programme committee, representing the JRA and access activities of Laserlab-Europe, the Industrial Advisory Committee, and the expert groups of the network. Users of the transnational access programme and industrial representatives were actively involved in the programme setup.

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The programme committee proposed the following five session topics:

- 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. At the end of each session, ample time was provided for discussion with the speakers, which was actively used.

The conference was fully open to participants from outside Laserlab-Europe. For interested companies, exhibition space was provided with stands showcasing their innovations. In addition, industrial representatives were invited to participate in the sessions.

Group picture

On the first day, Sylvie Jacquemot, the coordinator of Laserlab-Europe, together with Luis Silva, the President of the School Council of IST, welcomed the attendees and gave a short introduction to the Laserlab-Europe project and the position of IST in the science landscape in Portugal.

In the following, some JRA highlights are listed that were presented during the sessions:

Session 2: Attoscience

JRA PRISES - PRImary and SEcondary Sources, Task 3.3 X-ray absorption fine structure (XAFS) spectroscopy using laser-driven sources of X-ray radiation

Attosecond soft X-ray spectroscopy for studying many-body dynamics in condensed matter systems

Themistoklis Sidiropoulos (ICFO, MBI)

The excitation of matter with intense, ultrashort pulses of light induces a non-equilibrium state that can give rise to electronic, structural or magnetic phase transitions with exciting prospects

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for novel device functionalities. The optically excited non-equilibrium state relaxes through interactions between charge carriers, phonons or other quasiparticles that occur over a large time and energy scale. The study of such many-body dynamics, therefore, requires techniques which are capable of following the flow of energy over all relevant scales.

Light emitted through the process of high-harmonic generation meets this challenge as pulse lengths can be in the attosecond domain with photon energies reaching the soft X-ray regime [1,2]. The absorption of X-rays is particularly intriguing as it allows the probing of changes in the electronic density of states above and below the Fermi energy. Consequently, the broadband spectrum of a soft X-ray high-harmonic pulse is ideal for investigating the many-body interactions of a non-equilibrium state.

In this talk I provide an overview of recent progress in attosecond science and demonstrate its application to the study of many-body dynamics over a wide temporal range. Here, I focus on the energy flow in optically excited graphite [3,4], the laser-induced spin dynamics in GdFe and the laser-induced oxidation dynamics of Ti.

[1] A.M. Summers et al., Realizing Attosecond Core-Level X-ray Spectroscopy for the Investigation of Condensed Matter Systems, J. Ultrafast Sci. 3, 4 (2023).

[2] J. Biegert, Attosecond Science: A new Era for Many-Body Physics, Europhysics News 55 (1), 12-15 (2024)

[3] T.P.H. Sidiropoulos et al., Probing the Energy Conversion Pathways between Light, Carriers, and Lattice in Real Time with Attosecond Core-Level Spectroscopy, Phys. Rev. X 11, 041060 (2021)

[4] T.P.H. Sidiropoulos et al., Enhanced optical conductivity and many-body effects in strongly-driven photo-excited semi-metallic graphite, Nat. Commun. 14, 7407 (2023)

Session 4a: Lasers for oncology

JRA ALTIS - Advanced Laser-based Techniques for Imaging and Spectroscopy in material science and biomedicine

Delineation of gastrointestinal tumour biopsies using a fibre-based autofluorescence lifetime imaging probe

Riccardo Cicchi (LENS)

Autofluorescence spectroscopy has emerged in recent years as a powerful tool to report label-free contrast between normal and diseased tissues. In particular, Fluorescence Lifetime Imaging Microscopy (FLIM) has shown detailed profiles of tissue autofluorescence, enabling more informed and rapid tissue characterization, with the potential for translation from the research labs to bedside. Time-correlated single-photon counting (TCSPC) is recognized as the "gold-standard" method for fluorescence lifetime measurements but its use under bright background conditions is prevented by the inability to distinguish fluorescence from background photons. This limitation can be circumvented by means of an asynchronous detection of the fluorescence signal with respect to an external white light source [1]. We report here the test of our autofluorescence lifetime imaging probe device, already employed for real-time mapping of degraded articular cartilage from pig [1, 2], on four different clinical cases. More in detail, we examined four biopsies, one from a hepatocellular carcinoma (HCC), another from an intrahepatic cholangiocarcinoma (ICC), one from a gastrointestinal stromal tumor (GIST) and the last one from pancreatic ductal adenocarcinoma (PDCA). The results suggest that our autofluorescence lifetime imaging probe, together with phasor analysis, can offer a real-time tool to observe spectral and lifetime contrast on fresh tissues and, thus, is a suitable candidate for improving in situ tissue diagnostics during surgery.

[1] Lagarto et al., Real-time fiber-based fluorescence lifetime imaging with synchronous external illumination: A new path for clinical translation, J. Biophot. 13, e201960119 (2020)

[2] Lagarto et al., Simultaneous fluorescence lifetime and Raman fiber-based mapping of tissues, Opt. Lett. 45, 2247-2249 (2020)

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Session 4b: Lasers for imaging & diagnosing life

JRA ALTIS - Advanced Laser-based Techniques for Imaging and Spectroscopy in material science and biomedicine, Task 2.1 High-resolution imaging of intact biological samples

Photo(opto)-acoustic imaging and sensing in time and frequency domain for Life Sciences

Giannis Zacharakis (IESL-FORTH)

Photo(opto)-acoustic imaging has emerged as a powerful technique in life sciences, offering unique capabilities for visualizing biological structures and processes with high resolution and contrast. This presentation delves into the advancements and applications of photo(opto)-acoustic imaging and sensing, focusing on both time and frequency domains. By combining optical excitation with acoustic detection, photo(opto)-acoustic imaging enables non-invasive visualization of tissue morphology, vascular dynamics, and molecular signatures. We explore the principles behind photoacoustic imaging, highlighting its versatility in studying biological phenomena at various spatial and temporal scales. Additionally, we discuss recent developments in time- and frequency-domain photoacoustic techniques, and hybrid techniques concurrently capturing both non-radiative and radiative molecular relaxations in biological tissues, showcasing their potential for functional imaging, spectroscopy, and molecular sensing. These methods have been applied in a variety of different fields such as imaging of anatomy, biological function and pathology, health and welfare of animals, pathogen infections in plants, embryogenesis and development, cultural heritage, detection of adulteration and contaminants in food and fuel and the detection of biomarkers related to cardiovascular health and pathology. These case studies and experimental demonstrations illustrate the significant contributions of photo(opto)-acoustic imaging and sensing to advancing our understanding of life sciences and biomedical research.

[1] G.J. Tserevelakis et al., Hybrid confocal fluorescence and photoacoustic microscopy for the label-free investigation of melanin accumulation in fish scales, Sci. Rep. 12, 7173 (2022)

[2] G.J. Tserevelakis et al., Full image reconstruction in frequency-domain photoacoustic microscopy by means of a low-cost I/Q demodulator, Opt. Lett. 46, 4718-4721 (2021)

[3] G.J. Tserevelakis and G. Zacharakis, High precision photoacoustic interferometer for the determination of the speed of sound in liquid media, Opt. Exp. 30, 28559 (2022)

Immuno-OCT: Structural and molecular sensitive imaging *in vivo* at unprecedented resolution

JRA ALTIS - Advanced Laser-based Techniques for Imaging and Spectroscopy in material science and biomedicine, Task 2.2 Translational research: from biophotonics to clinical use

Johannes F. de Boer (LLAMS VUA)

Current clinical medicine relies on MRI and CT for structural imaging, and immuno-PET/SPECT for molecular specificity. The combination of structural imaging and molecular specific imaging provides detailed information about expression of proteins and cell surface receptors *in vivo* in humans. PET-CT/MRI has become an essential component of personalized medicine. However, the resolution of MRI/CT is just under a millimeter, while the resolution of PET is limited to about 2-10 millimeters, insufficient for early disease detection. Moreover, PET is associated with radiation burden of ligands labeled with a radiotracer and can image only one labeled ligand at a time.

I will present Immuno-OCT, the optical equivalent of PETCT/ MRI with a 10 to 100 fold better resolution. Immuno-OCT integrates three-dimensional endoscopic Optical Coherence Tomography (OCT) for structural information with imaging of fluorescently labeled monoclonal antibodies for molecular specificity. To image the hollow organs accessible by endoscopy,

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miniature motorized catheters were developed. In the presentation I will focus on Polarization sensitive OCT for lung diseases and Immuno-OCT esophageal cancer. *In vivo* human Immuno-OCT results in the first patient will be presented.

[1] F. Feroldi et al., High resolution combined molecular and structural optical imaging of colorectal cancer in a xenograft mouse model, Biomed. Opt. Express 9, 6186-6204 (2018)

[2] F. Feroldi et al., In vivo multifunctional optical coherence tomography at the periphery of the lungs, Biomed. Opt. Express 10, 3070-3091 (2019)

The Joint JRA meeting concluded with a tour of the laser laboratories at IST. All presentations of the different sessions are available for the project members on the Laserlab-Europe cloud.

4 Conclusions and outlook

In addition to the individual JRA meetings allowing for a more in-depth overview of the work and participation in the discussions, the format of the Joint JRA meetings is important for stimulating future collaborations between the participants in the project and external partners from academia and industry. The feedback from participants in general has been very positive, emphasising the need for future similar events, specifically addressing external participants.

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