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the Laserlab-Europe
project, and discuss
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LASERLAB- EUROPE

Conference

27-29 MAY 2024



Instituto Superior Técnico (IST)
Lisbon, Portugal





Welcome to the Laserlab-Europe Conference 2024!

We are delighted you could join us for our conference on the latest advances in laser technology and laser science.

Hosted by Laserlab-Europe at Instituto Superior Técnico, Lisbon, this conference serves as a platform to display results and access highlights from the Laserlab-Europe project, and foster collaboration within the laser community and beyond.

Spanning three days, our conference offers a comprehensive program from sessions exploring the applications of lasers to discussions on cutting-edge attoscience. Distinguished speakers, including Nobel laureate Anne L'Huillier from Lund University, will share their expertise.

In addition to our stimulating sessions, the conference will feature an exhibition space where companies set up their stands showcasing their innovations, providing a unique opportunity for networking and collaboration.

We look forward to welcoming you to the Laserlab-Europe Conference 2024.

[Sylvie Jacquemot](#)

Venue



[Centro de Congressos do IST](#)

Instituto Superior Técnico, Campus Alameda
Av. Rovisco Pais, 1, 1049-001 Lisbon

Agenda

27 May	28 May	29 May
08:30-10:00 Access Board Meeting <i>(Internal event)</i>	09:00-11:10 Session 3: Lasers in a multi-instrumental world	09:00-10:30 Session 5: Lasers and laser-based instruments for the future
10:00-12:25 Session 1: Lasers for Catalysis	11:40-13:30 Session 4a: Lasers for oncology	11:00-15:30 Laserlab-Europe AISBL General Assembly <i>(Internal event)</i>
14:00-17:20 Session 2: Attoscience	14:30-17:30 Session 4b: Lasers for Imaging & Diagnosing Life	
17:30-18:30 Public Lecture by Anne L'Huillier (Lund University)	17:30 City Tour	16:00 Lab Tour at IST
19:30 Working Dinner <i>(Internal event)</i>		

Exhibition

On all three days, nine companies will showcase their latest solutions and technologies. The EU projects ReMade@ARI and RIANA will inform interested participants about transnational access opportunities for researchers and companies in nanoscience and materials science.

[See pages 29-32 for an overview of all exhibitors.](#)

27 May

08:30-10:00	<i>Access Board Meeting (internal event)</i>
10:00-10:15	Welcome by Luis Silva (President of the School Council of IST) and Sylvie Jacquemot (Laserlab-Europe Project Coordinator)
10:15-12:25	Session 1: Lasers for catalysis - Introduction by Marius Horch (FU Berlin) - Photocatalytic hydrogen generation and CO2 reduction using inorganic and organic photosensitisers. Using time resolved spectroscopy to aid in identifying the intermediates in the photocatalytic processes, Mary Pryce (Dublin City University) - Light-induced catalysis using plasmonic metal nanoparticles, Sven Askes (Vrije Universiteit Amsterdam) - Catalysis in the light of lasers, Johan Zetterberg (Lund Laser Center) - Unveiling key intermediates in organocatalyzed reactions by IR ion spectroscopy, Davide Corinti (Sapienza Università di Roma) - Discussion
12:25-14:00	<i>Lunch</i>
14:00-17:20	Session 2: Attoscience - Introduction by Marc Vrakking (Max Born Institute) - Capturing coherent electron dynamics in chiral molecules, Vincent Wanie (DESY) - Controlling high order harmonic focusing properties: spatial shaping to reduce XUV chromatic aberrations, Eric Constant (Institut Lumière Matière) - Attosecond soft X-ray spectroscopy for studying many-body dynamics in condensed matter systems, Themistoklis Sidiropoulos (ICFO, Max Born Institute)
15:10-15:40	<i>Coffee Break</i> - Control of high harmonic XUV source wavefront, Amelle Zair (King's College London) - Towards a standard for laser pulse compressibility, Fabio Giambruno (Sphere Ultrafast Photonics) - All-attosecond transient absorption spectroscopy using HHG, Bernd Schuette (Max Born Institute) - Discussion
17:20-17:30	<i>Break</i>
17:30-18:30	Public lecture "The route to attosecond pulses" by Anne L'Huillier (Lund University) moderated by John Collier (Laserlab-Europe)
19:30	<i>Project internal Working Dinner</i>

28 May

09:00-11:10	Session 3: Lasers in a multi-instrumental world - Introduction by Daniela Stozno (Laserlab-Europe) - ReMade@ARI: Tailor-made Access Routes for Advancing Materials Development for a Circular Economy, Barbara Schramm (HZDR) - RIANA: Research Infrastructure Access in NANoscience & nanotechnology, Michael E. Stuckelberger (DESY) - Lasers4EU: A multi-faceted approach for demand-driven fundamental and applied research, Sylvie Jacquemot (LULI) - Recent developments in the applications of X-ray Free Electron Lasers, Majed Chergui (EPFL, Elettra Sincrotrone Trieste) - Discussion
11:10-11:40	<i>Coffee Break</i>
11:40-13:30	Session 4a: Lasers for oncology - Introduction by Dino Jaroszynski (University of Strathclyde) - Delineation of gastrointestinal tumour biopsies using a fibre-based autofluorescence lifetime imaging probe, Riccardo Cicchi (LENS) - Laser-driven, very-high energy, electrons (VHEE): a versatile tool for radiation biology, Alessandro Flacco (LOA) - Preliminary results of radiobiology experiments by laser driven ionizing radiation beams, Emília Rita Szabó (ELI ALPS) - Discussion
13:30-14:30	<i>Lunch</i>
14:30-17:30	Session 4b: Lasers for imaging & diagnosing life - Introduction by Luis Arnaut (Coimbra Laser Lab) - Photo(opto)-acoustic imaging and sensing in time and frequency domain for Life Sciences, Giannis Zacharakis (IESL-FORTH) - Femtosecond pulses for Pathology, Frank van Mourik (Flash Pathology) - Developing Photoactive Transition Metal Complexes Towards DNA Targeted Diagnostics and Therapeutics, Susan Quinn (University College Dublin)
15:40-16:10	<i>Coffee Break</i> - Optical Photothermal infrared imaging using free electron laser as pump source, Christoph Krafft (Leibniz IPHT) - Immuno-OCT: Structural and molecular sensitive imaging in vivo at unprecedented resolution, Johannes F. de Boer (Vrije Universiteit Amsterdam) - Discussion
17:30	<i>City Tour</i>

29 May

09:00-10:30	Session 5: Lasers and laser-based instruments for the future - Introduction by Sébastien Le Pape (LULI) - Laser Drivers for Inertial Confinement Fusion, Mariastefania De Vido (Central Laser Facility) - Manipulation of laser-based secondary sources for enhanced EUV and x-rays, Marta Fajardo (Instituto Superior Técnico) - Discussion
10:30-11:00	<i>Coffee Break</i>
11:00-15:30	Laserlab-Europe AISBL General Assembly (internal event) <i>The agenda has been distributed separately to members of the Laserlab-Europe AISBL</i>
13:00-14:00	<i>Lunch</i>
16:00-17:00	Lab Tour at Instituto Superior Técnico (IST)

Public Lecture by Nobel laureate

Anne L'Huillier (Lund University)

The route to attosecond pulses

When an intense laser interacts with a gas of atoms, high-order harmonics are generated. In the time domain, this radiation forms a train of extremely short light pulses, of the order of 100 attoseconds. Attosecond pulses allow the study of the dynamics of electrons in atoms and molecules, using pump-probe techniques. This presentation will highlight some of the key steps of the field of attosecond science.



Session 1: Lasers for catalysis

Photocatalytic hydrogen generation and CO₂ reduction using inorganic and organic photosensitisers. Using time resolved spectroscopy to aid in identifying the intermediates in the photocatalytic processes.

Mary T Pryce¹

¹ School of Chemical Sciences, Dublin City University

The development of renewable energy sources is a global challenge, as we seek new routes to address climate change and energy security. The development of new materials that can act as light harvesting materials for photocatalytic water splitting has been extensively studied by us and others. [1-4] The ultimate goal in our studies is to incorporate these assemblies into dye-sensitised photoelectrochemical cells. We have developed a range of materials based on inorganic and organic materials. Our focus is not only hydrogen generation but also CO₂ reduction. While many studies develop new photocatalytic assemblies for hydrogen production/CO₂ reduction, fewer studies centre on the intermediates, and the experimental methods employed to identify such intermediates. We have performed in depth time-resolved studies to probe the excited states in the compounds studied. Our studies indicate that many parameters must be considered when designing such assemblies. The presentation will centre on the materials developed, the spectroscopic techniques (TRIR, TAS, spectroelectrochemistry) employed to probe the intermediates and the importance of the photocatalytic conditions on the amount of hydrogen generated.

References

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Part of the research leading to these results has received funding from the European Union's Horizon 2020 research and innovation programme through LASERLAB-EUROPE.

Session 1: Lasers for catalysis

Light-pulsed nanoscale heating for catalytic control

Sven Askes¹

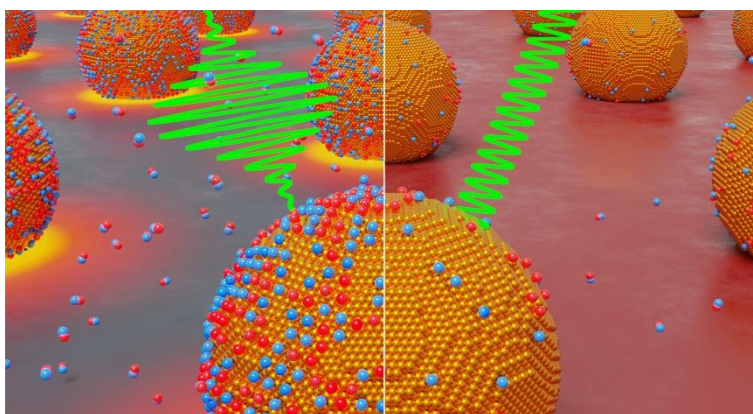
¹ Department of Physics and Astronomy, Vrije Universiteit Amsterdam

What can pulsed lasers do for catalysis, other than use them to *study* catalytic mechanisms and material properties? What would happen if we use pulsed lasers to *drive* catalysis? In this talk, I will address this central question.

Most conventional reactors in chemical industry use catalyst nanomaterials to speed up reactions, but their operation at a steady-state temperature impedes our ability to improve their rate, selectivity, and energy efficiency. Further, heat is currently indiscriminately applied to the entire reactor, leading to slow and energy-inefficient temperature control.

To go beyond these limitations, applying short heat pulses specifically to the catalyst at μs or faster timescales theoretically leads to $>100\times$ higher reaction yield, lower energy use, and a controlled product distribution. However, such pulsed heating has remained out of reach because it remains challenging to heat catalysts selectively and fast enough.

With this presentation, I will propose novel light-based strategies to break this paradigm, based on optical pulses and plasmonic materials that convert light to heat with nanoscale specificity. I will demonstrate with numerical calculations that the modulation of heat pulse timings (how intense, how long, how often) can grant access to a normally unreachable reaction landscape, with dynamic tunability of rate, energy efficiency, and selectivity. These results pave the way to a more sustainable and process-intense operation of catalytic reactors.



References

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Session 1: Lasers for catalysis

Catalysis in the light of lasers

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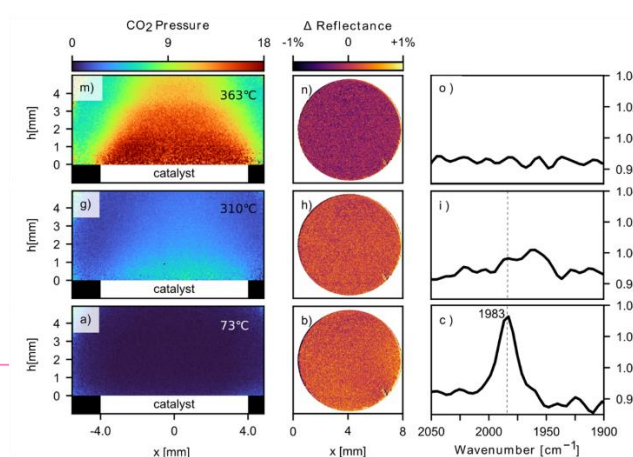
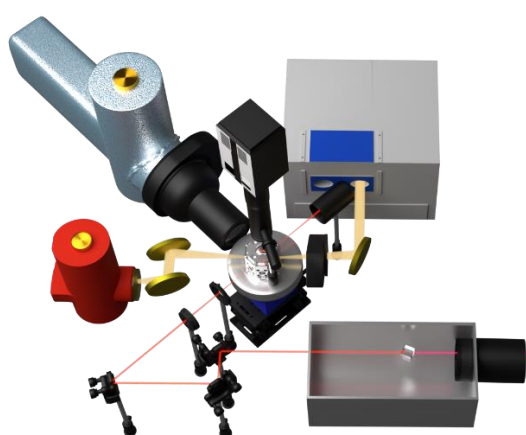
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Catalysis is due to its unique attributes – to lower energy barriers and its selectivity – a key process in the transition to a fossil free society. The transition needs new catalysts and more efficient processes to target new reactions. Today, we lack a detailed understanding on a mesoscopic- and atomistic scale and of the interface close to the surface. To gain these insights, studies at realistic conditions, so-called *operando*, are crucial to couple structure to activity or determine active sites on the surface. At realistic conditions, however, fluidic phenomena will affect and alter the surface and the reaction behaviour. To then untangle the different contributions and solve e.g. cause and effect problems, several parameters need to be measured simultaneously and at different scales. By using lasers and other photon-in photon-out techniques that are relatively insensitive to elevated pressures it is possible to image both surface and the interface simultaneously, with high spatial and temporal resolution.

This contribution will focus on the combination of several techniques, complemented with synchrotron-based methods, and how the information from the surface and gas phase can be correlated and thereby aid in the interpretation of the data.



Session 1: Lasers for catalysis

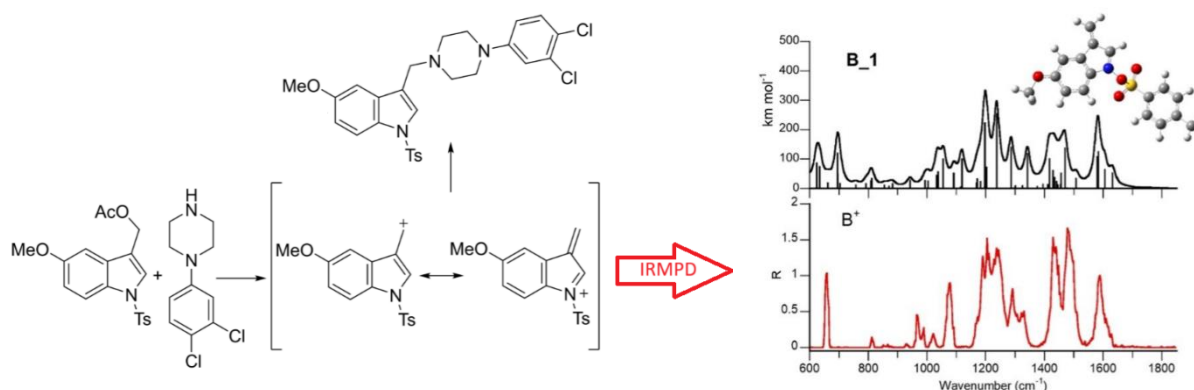
Unveiling key intermediates in organocatalyzed reactions by IR ion spectroscopy

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Organic catalysts are increasingly being utilized to catalyze organic reactions that were previously dependent on organometallic catalysts, with the aim of reducing the use of scarce metals, such as palladium. To fully exploit the potential of this catalyst class, characterization of the reactive intermediates involved in the reaction activation is essential. In this context, mass spectrometry (MS) represents a powerful method for analyzing both online and offline reaction mixtures. MS results can complement theoretical data on reaction mechanisms by isolating and identifying of reaction intermediates. However, MS analysis often lacks in providing structural information, particularly when dealing with isomeric species. For this reason, we turned to IR multiple photon dissociation (IRMPD) ion spectroscopy, utilizing the experimental platform available at the FELIX laboratory (Nijmegen, Netherlands). Here, the light of the free electron laser is allowed to interact with mass-selected ions trapped in the cell of an ion trap mass spectrometer, allowing for vibrational and structural characterization of ionic intermediates. This contribution presents results obtained from the analysis of reaction intermediates formed during the nucleophilic substitution of different indolylmethylacetates in the presence of carbonate salts, a green pathway that circumvents the use of Pd catalysts.[1] Additionally, results from the Michael addition of either cyclic or α,β -unsaturated ketones to trans- β -nitrostyrene in the presence of organocatalysts, such as 9-amino(9-deoxy)epi-quinine, will be discussed.



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Part of the research leading to these results has received funding from the European Union's Horizon 2020 research and innovation programme through LASERLAB-EUROPE.

Session 2: Attoscience

Capturing coherent electron dynamics in chiral molecules

Vincent Wanie¹, Etienne Bloch², Erik P. Månsson¹, Lorenzo Colaizzi^{1,3}, Sergey Ryabchuk^{3,4}, Krishna Saraswathula^{1,3}, Andres F. Ordonez⁵, David Ayuso^{5,6}, Olga Smirnova^{6,7}, Andrea Trabattoni^{1,8}, Valérie Blanchet², Nadia Ben Amor⁹, Marie-Catherine Heitz⁹, Yann Mairesse², Bernard Pons², Francesca Calegari^{1,3,4}

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Laser-driven light sources that deliver vacuum ultraviolet (VUV) or ultraviolet (UV) pulses with a duration of a few femtoseconds (fs) are currently being developed for time-resolved spectroscopic applications [1-2]: Their characteristic photon energy combined with unprecedented time resolution opens up a completely new niche for experiments, enabling a perturbative excitation - below the ionization threshold - and a subsequent real-time tracking of ultrafast electronic processes in neutral molecules occurring over only a few fs.

In this context, I will present the capabilities of our few-fs UV light sources [3,4] to reveal the contribution of electronic coherences to molecular chirality, a property that is important for various applications such as molecular switches and circularly polarized light emission and detection [5,6]. Using time-resolved photoelectron circular dichroism [7], an ultrafast inversion of the molecular chiroptical response is observed in less than 10 fs after UV-excitation of methyl-lactate molecules, which is captured by modulations of the detected photoelectron angular distribution. Numerical simulations show that the ultrafast electronic motion triggered by the UV radiation generates chiral currents, providing important perspectives to apply the concept of charge-directed reactivity to chiral molecules [8]. I will discuss an example where such chiral currents could be exploited to control the photodissociation direction of chiral methyl-lactate molecules.

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Session 2: Attoscience

Controlling high order harmonic focusing properties: spatial shaping to reduce XUV chromatic aberrations

Campaign LLC002578

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Attosecond beams created by high-order harmonic generation (HHG) in gases can exhibit large chromatic aberrations [1-4]. This is inherent to the broad bandwidth of the attosecond pulses and to the wavelength-dependent nonlinear light-matter interaction arising in HHG. When the driving laser intensity varies radially in the generating medium, as for Gaussian driving beams, the apparent source position of the harmonics differs significantly from one harmonic order to the next, thus inducing chromatic aberrations. They affect the achievable intensity and duration of the attosecond pulses when they are focused on a target.

During a Laserlab-Europe experimental campaign, LLC002578, performed at the Lund Laser Center, we have studied these XUV chromatic aberrations [5]. We have confirmed that they are significant. We have also shown that they can be reduced by spatially shaping the fundamental beam and generating high-order harmonics with a driver having a near flat-top profile inside the gas medium. By measuring both the intensity profile and wavefront curvature for each harmonic in a plane, we access the extreme ultra-violet (XUV) beam properties and investigate these properties near focus. We observe that controlling chromatic aberrations by flat-top spatial shaping strongly reduces the variation of the XUV spectrum on the beam axis during propagation and, in return, the longitudinal evolution the temporal profiles of the focused attosecond pulses.

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Part of the research leading to these results has received funding from the European Union's Horizon 2020 research and innovation programme through LASERLAB-EUROPE.

Session 2: Attoscience

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

Themistoklis Sidiropoulos ^{1, 2}

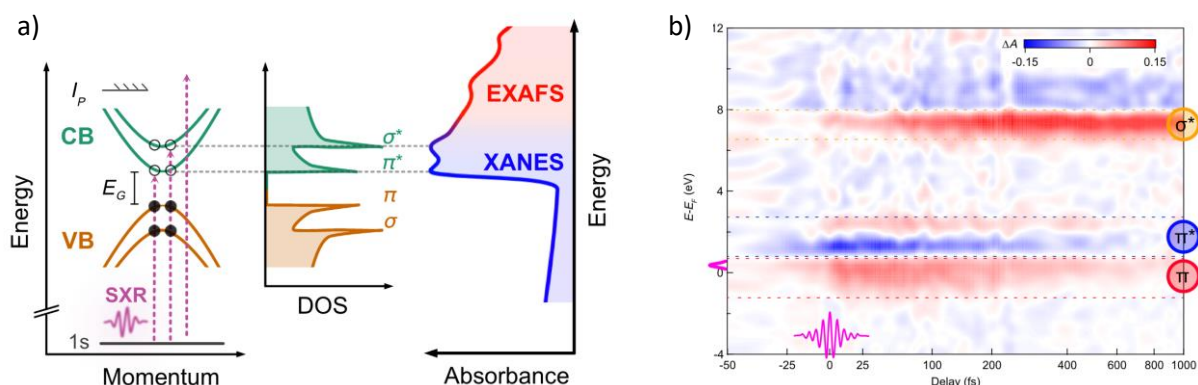
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The excitation of matter with intense, ultrashort pulses of light induces a non-equilibrium state that can give rise to electronic, structural or magnetic phase transitions with exciting prospects for novel device functionalities. The optically excited 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 challenges 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 will 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 will focus on the energy flow in optically excited graphite [3,4], the laser-induced spin dynamics in GdFe [5] and the laser-induced oxidation dynamics of Ti.



(a) Schematic of X-ray absorption spectroscopy where soft X-rays (SXR) excite core-level electrons into free electronic states that becomes visible as sharp changes in the X-ray absorption profile [1]. The near-edge region (XANES) gives information about charge carrier occupation changes in the valence (VB) or conduction band (CB). The extended absorption spectrum (EXAFS) gives information about the crystal lattice. (b) Changes in the X-ray absorption spectrum of graphite for different delays after optical excitation with a near-infrared pulse [2].

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Session 2: Attoscience

Control of high harmonic XUV source wavefront

Amelle Zair¹

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High harmonic generation (HHG) [1] is a well-established process to produce reliably tabletop attosecond X-rays to XUV sources [2,3] pioneered by Anne L'Huillier, Pierre Agostini and Ferenc Krausz who received the Nobel Prize in Physics in 2023. These sources are now used in pump-probe experiments to time-resolve the spectroscopy of isolated systems, usually in gas phase [4,5], relevant to the understanding of ultrafast charge migrations and transfer in matter. The extension of these pump-probe experiments to more complex systems lies in achieving high flux on target. The high flux on target is equally important to many applications of the XUV source such as high-resolution imaging, attosecond metrology and future applications to inspection procedure in industry. However, the high harmonic flux on target is limited by the low efficiency of the HHG process (10^{-8} - 10^{-4}) and locally by the wavefront of the high harmonics, which happened to be inhomogeneous across the high harmonic bandwidth. This inhomogeneity of wavefronts leads to chromatic foci across the XUV spectrum. It is essentially due to microscopic and macroscopic phases acquired by the XUV field during the HHG process. This chromaticity of the high-harmonic foci limits the attosecond capability of the source on target. It is therefore an important challenge to address for tabletop HHG source and their applications. In order to tackle the flux challenge, approaches have been demonstrated and can be categorized as the control of the HHG phase matching conditions [6,7] and the scaling up the HHG beamline to achieve more emitters from large scale generating media [8,9]. But all these techniques concentrate only on the increase of the HHG efficiency or emitters and do not correct for the wavefront mismatch. Optimizing the high-harmonics wavefront is therefore the key to high flux attosecond sources. One of our expertise at King's College London (KCL) is on spatio-temporal synthesis of laser field for optimization of high repetition rate HHG beamlines. We applied our approaches of tailoring the laser driver profiles into flat tops to HHG XUV wavefront optimization on scaling up beamlines, where the number of emitters is already to a high level.

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Part of the research leading to these results has received funding from the European Union's Horizon 2020 research and innovation programme through LASERLAB-EUROPE.

Session 2: Attoscience

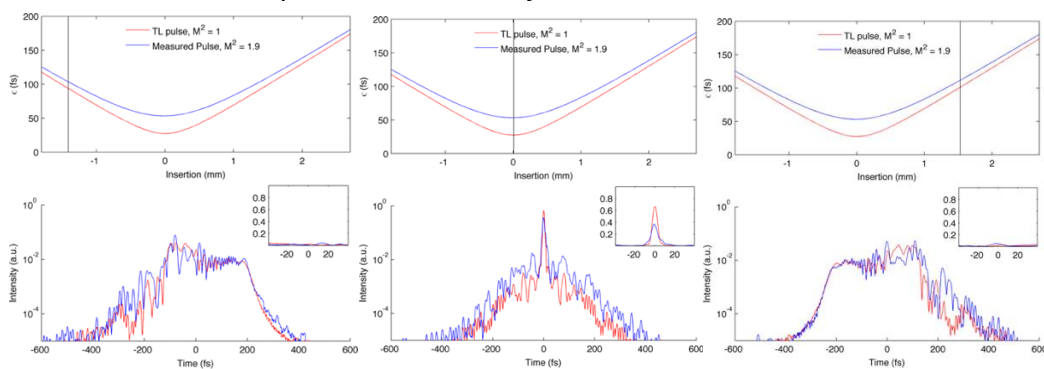
Towards a standard for laser pulse compressibility

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One of the most important characteristics of a laser is its intensity upon a target, not only because this determines the regime of the resulting light-matter interaction, but also because the ability to tightly focus light in space and in time – as done with ultrashort laser pulses – is a direct consequence of the unique spatiotemporal coherence properties of the laser. Over 30 years ago, a simple and intuitive metric of the spatial quality of a laser beam was introduced by A. E. Siegman – the M^2 factor [1] – which tells us how the propagation and focusing abilities of a given beam deviate from those of an ideal TEM₀₀ Gaussian beam. In 2002, G. Rousseau and co-workers introduced a pulse quality factor combining the rms width of the temporal autocorrelation with that of the pulse power spectrum, with the goal of facilitating the analysis of autocorrelations [2]. Here we propose a measurement technique for quantifying laser pulse quality – defined as temporal compressibility – based on extending the concept of the spatial M^2 factor to arbitrary temporal pulse shapes via a temporal M^2 factor, or M_t^2 . The technique involves measuring the pulse profile around the maximum compression point, which can be directly obtained from a single d-scan measurement [3]. We apply this technique to broadband pulses from a hollow-fibre system comprising a chirped mirror and wedge compressor. The figure (top) shows the resulting pulse duration, as given by the second order moment of the temporal intensity, for three different wedge insertions around the temporal focus ($M_t^2=1.9$) compared to an ideal flat phase pulse ($M_t^2=1$), together with the corresponding pulse temporal profiles (bottom). We have verified that the temporal M^2 allows the easy and intuitive communication of the temporal compressibility of a pulse, as its value increases with phase aberrations (e.g., increasing third- or fourth-order dispersion), as expected, is independent of the type of wedge glass and pulse characterization technique used, and is robust with respect to noise and systematic errors.



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Session 2: Attoscience

All-attosecond transient absorption spectroscopy using HHG

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The ability to perform attosecond-pump attosecond-probe spectroscopy (APAPS) is a longstanding goal in ultrafast science. First pioneering APAPS experiments were performed based on high-harmonic generation (HHG) in 2011 [1] and 2013 [2] using ion spectroscopy. However, this has not led to a significant number of published APAPS results in the decade following these first results, which may be explained by the fact that specialized laser systems operating at low repetition rates of 10 Hz were used in Refs. [1, 2]. Following the slow progress in HHG-based APAPS experiments, the pursuit of APAPS has in recent years to a significant extent shifted to free-electron laser facilities like the LCLS, where first APAPS experiments at soft X-ray wavelengths have been demonstrated [3, 4].

Recently, we have made substantial progress in the development of HHG-based APAPS: For the first time we have demonstrated APAPS at a repetition rate of 1 kHz [5], for which a turn-key commercial laser system with a highly stable output was used. Here we will present results of the first HHG-based all-attosecond transient absorption spectroscopy (AATAS) experiments using a combination of two extreme-ultraviolet pulses. In a first experiment, we have ionized Kr by an intense attosecond pulse, and we have observed electronic coherences in the generated Kr⁺ ions using a time-delayed attosecond probe pulse. This is analogous to the first attosecond transient absorption spectroscopy (ATAS) experiment [6], where Kr was ionized by a strong laser field. We will further show that our approach is applicable to more complex systems: In an AATAS experiment performed in SF₆ molecules, a transient electronic structure was observed during the first few femtoseconds after ionization.

Our approach has the potential to provide an entirely new perspective on extremely fast electron dynamics in atoms, molecules and solids. When the challenge of obtaining high attosecond pulse intensities can be overcome, which we have recently achieved in our laboratory, HHG represents an ideal source for AATAS, due to the high stability and accessibility and due to the broad bandwidths covering more than one octave that can be generated.

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Session 3:

Lasers in a multi-instrumental world

Recent developments in the applications of X-ray Free Electron Lasers

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X-ray Free Electron lasers (XFELs) have been a game changer in time-resolved X-ray spectroscopic studies of matter thanks to their ultrashort pulses, high photon flux/pulse and photon energy range. I will briefly present some of the most representative studies carried out on chemical, biological systems and solid materials.

I will then dwell on trends that aim at exploiting the high photon fluxes and coherent properties of the XFEL beams, in order to implement non-linear X-ray spectroscopies, akin to what happened in the 1960s, after the birth of the laser.¹ Indeed, techniques such as multiphoton absorption, second-harmonic generation and four-wave mixing have been implemented, and in the case of Transient Grating core-level spectroscopy, now routinely used.²

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Session 4a: Lasers for oncology

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

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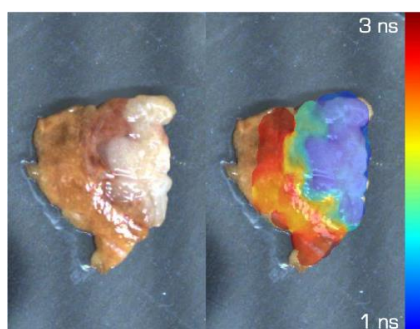
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Autofluorescence spectroscopy has emerged in recent years as a powerful tool to report label-free contrast between normal and diseased tissues. In particular, Fluorescence Lifetime Imaging Microscopy (FLIM) has shown detailed profiles of tissue autofluorescence, 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.



A white light image (on the left) of a fresh biopsy of a hepatocellular carcinoma specimen, together with the corresponding autofluorescence lifetime map, presented as augmented-reality image (on the right).

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Session 4a: Lasers for oncology

Laser-driven, very-high energy, electrons (VHEE): a versatile tool for radiation biology

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Very-high energy electrons are being researched as a potential radiation quality for novel therapeutic protocols in radiation therapy. Electrons with energies higher than 50 MeV do have a sufficient penetration for deep seated tumors. Moreover, the high deposited dose makes them interesting for high and ultra-high dose-rates therapy, as in FLASH [1].

Laser-driven acceleration schemes are able to produce electron sources at energies relevant for irradiation of biological samples, in principle compatible with human therapeutic protocols (100 – 250 MeV) in a rather compact setup, thanks to the extremely high laser-plasma accelerating gradient. Laser-driven particle sources show a very peculiar temporal profile, with instantaneous dose rates as high as 10^9 Gy/s, where dose is deposited in separated fractions of ultra-short duration. This dose deposition modality can trigger previously unexplored toxicity mechanisms in living organisms [2], related to the very high dose rates, which are currently a trending topic in the radiobiology and medical physics communities.

In my contribution I will present recent activities and results obtained at the LOA around the setup of a pre-clinical laser-driven irradiation platform for VHEEs, and its use for a number of irradiation experiments using in-vitro, ex-vivo and in-vivo biological targets.

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Session 4a: Lasers for oncology

Preliminary results of radiobiology experiments by laser driven ionizing radiation beams

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Radiotherapy is an important and rapidly advancing modality in cancer treatment. Over the past decade, laser-driven plasma-based particle accelerators (LPAs) and beam sources have been developed to provide short (ns-ps) and ultrashort (fs) electron, neutron, proton/ion, and X-ray pulses in compact, laboratory-scale equipment that have reached a level of capability suitable for radiobiology experiments. LPAs, with their extremely increased time and spatial resolution in dose delivery, alongside special irradiation methods such as very high energy electron, Micro beam RT, and ultra-high dose rate, hold great promise for radiation oncology. The development of new radiotherapeutic approaches is a long time process where the general concept should be proven from time to time even though clinical requirements. At the actual status of development low energy, ultrahigh dose rate, limited-size beams are available under technical conditions for preclinical experiments.

To quantify the acute normal tissue reactions of the different LPA irradiation approaches, including FLASH effect evaluation and RBE definition we have optimized and validated the zebrafish embryo model as a vertebrate organism for *in vivo* experiments. This model is very suitable for radiobiology experiments due to the number of offspring and their small size (1mm diameter 24 h post fertilization (hpf)), the latter is meaningful at limited beam spot sizes.

At the Draco system of the HZDR Institute, we performed the first radiobiological studies on zebrafish embryos using a laser proton source. The aim of the experiment was the confirmation of a protective effect of ultra-high dose rate proton irradiation at the laser system comparable to the recently described FLASH effect.

Recently laser-driven neutron sources such as fast neutrons generated by deuterium-deuterium (*D-D*) fusion reactions attracted lots of attention due to their potential applications in various fields particularly in biology and medicine sciences. However, preliminary investigations have revealed that neutron yield generated by these experiments remains constrained by multivarious factors. The effect of such low-intensity neutron beams on biological samples is not well understood yet.

The first studies were carried out in collaboration with the NLTL of the University of Szeged, examining the impact of laser-generated neutrons on living organisms using zebrafish embryos. Radiobiological studies with laser-induced particles (proton and neutron) have shown encouraging results.

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Part of the research leading to these results has received funding from the European Union's Horizon 2020 research and innovation programme through LASERLAB-EUROPE.

Session 4b:

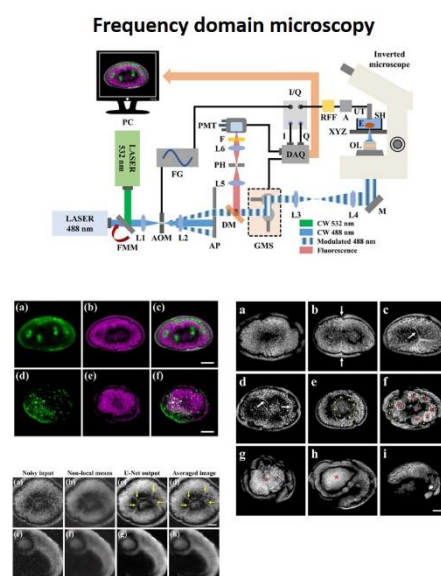
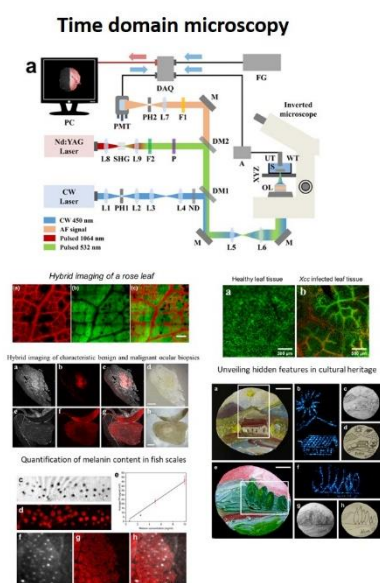
Lasers for imaging & diagnosing life

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

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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 will explore the principles behind photoacoustic imaging, highlighting its versatility in studying biological phenomena at various spatial and temporal scales. Additionally, we will 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.



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Session 4b:

Lasers for imaging & diagnosing life

Femtosecond pulses for Pathology

Frank van Mourik¹, Marie-Louise Groot²

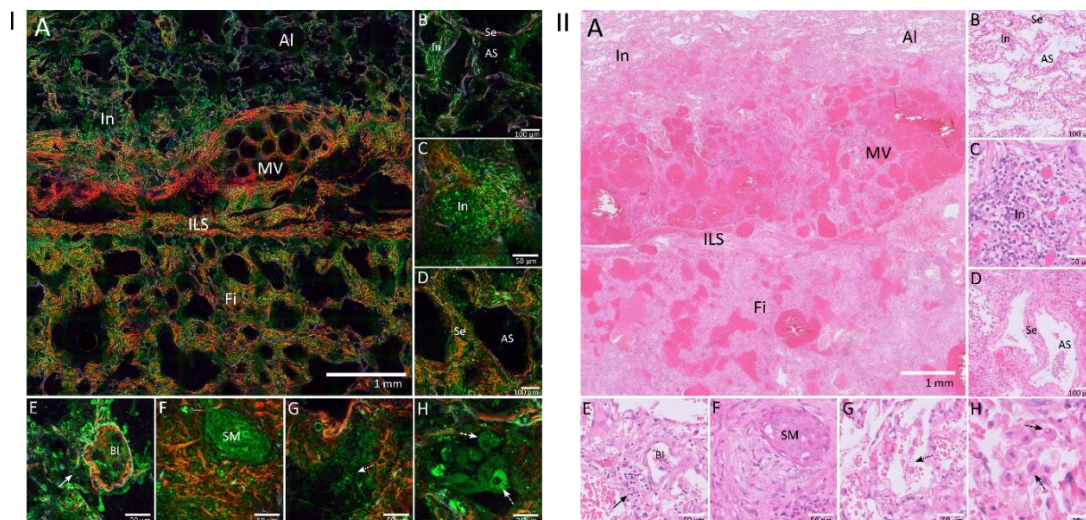
¹ Flash pathology b.v. Amsterdam, The Netherlands, www.flashpathology.com

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We demonstrate the power of non-linear microscopy for the analysis of medical/biological samples, especially for “Instant Pathology” of biopsy samples and excised tissue.

Pathology microscopy heavily relies on time-consuming preparation of the sample. It has to be chemically fixated, embedded, sliced, and stained. This precludes the use of classical pathology for intra-operative (bed-side) diagnostics. A variety of non-linear microscopy techniques have been developed that enable microscopy on fresh unprepared samples without any preparative steps, and which leave the sample intact.

Here we demonstrate the use of harmonics generation and multi-photon microscopy with femtosecond near-IR laser pulses. Results have been obtained in a matter of minutes on lung, brain, kidney and more using our compact mobile microscope in three hospitals in the Netherlands. The images below (details in [1]) compare typical results obtained with our microscope I, with the classical histology II. The visualization of cells, cell nuclei and connective tissue allow for a pathologist diagnosis in agreement with histology.



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Session 4b:

Lasers for imaging & diagnosing life

Developing Photoactive Transition Metal Complexes Towards DNA Targeted Diagnostics and Therapeutics

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Photoinduced processes of DNA binding metal polypyridyl complexes have a wide range of potential applications in the areas of photodynamic therapy, DNA imaging and diagnostics. We have extensively use time-resolved spectroscopy to study the excited state dynamics of these processes for intercalating ruthenium dppz (dipyridophenazine) polypyridyl complexes bound to DNA.¹⁻³ While the phenanthroline (phen) light-switch complexes can signal the presence of DNA, the tetraazaphenanthrene (TAP) complexes can cause photodamage by participate in direct one-electron photo-oxidation of guanine, which is sensitive to the local DNA environment and the binding orientation. In this talk I will describe how the diverse photochemistry exhibited by Osmium, Ruthenium and Chromium polypyridyl complexes can be used to target DNA structures.¹⁻⁵ In particular, I will show time-resolved methods, including time-resolved infrared (TRIR) complemented by structural and computational studies, can be used to identify the binding site of photoactive metal complexes in solution, and to monitor sensitized DNA photo-oxidation of both guanine and adenine in solution. Finally, I will describe recent results that show how the introduction of an infrared probe can act to report on the DNA binding site.⁶

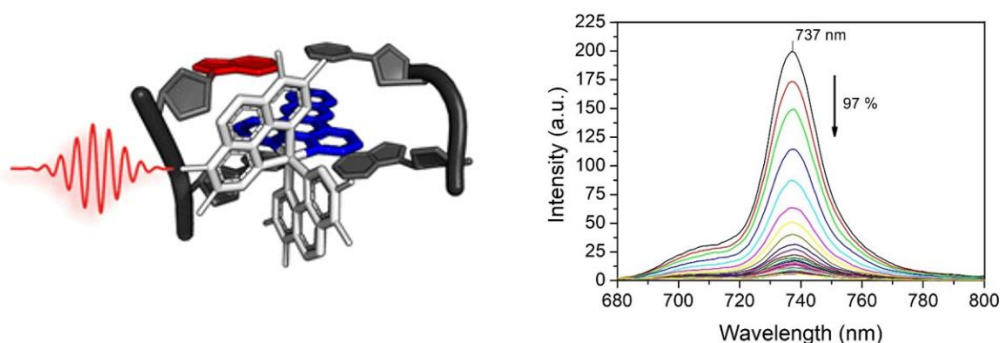


Figure: Schematic representation of the oxidation of adenine or guanine by an intercalated ligand centered excited state formed upon 400 nm excitation of $[\text{Cr}(\text{TMP})_2\text{dppz}]^{3+}$ and associated emission quenching.

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Session 4b:

Lasers for imaging & diagnosing life

Optical Photothermal infrared imaging using free electron laser as pump source

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The commercial optical photothermal infrared (OPTIR) instrument MIRage-R (Photothermal, USA) uses a pulsed, tunable mid-IR quantum cascade laser as pump source and a visible laser as probe source. The advantages of this detection principle was applied to microplastic detection [1] and single cell screening [2] at submicron imaging resolution and even in aqueous media. A widefield photothermal sensing instrument was introduced to increase imaging speed up to 1250 Hz [3]. An in-house developed OPTIR platform was applied to image the protein and lipid distribution in murine brain tissue (figure B), which is a key marker in brain tumors [4]. For extended OPTIR imaging, a mid-IR free-electron laser was coupled for the first time with an OPTIR microscope. More than 20-fold higher pump intensities enable to extend the assessable field to view to more than factor 5 which was also demonstrated for the protein and lipid distribution in murine brain tissue (figure D). Images at a series of wavenumbers were acquired to reconstruct the spectral information. The counter-propagation excitation and collection mode requires IR-transparent substrates. Calcium fluoride will be replaced by other substrate materials to extend the spectral range below 1000 cm^{-1} . Further details and biomedical prospects of the combined OPTIR-FEL approach will be presented.

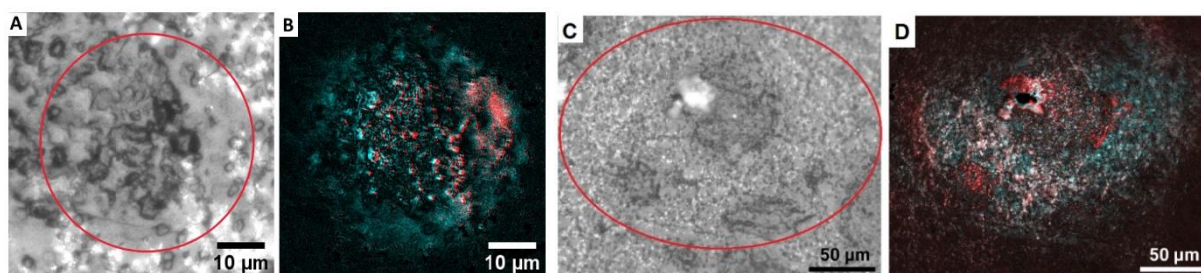


Figure 1: Photomicrographs (A, C) and overlay of OPTIR images at 1660 (cyan) and 1450 cm^{-1} (red) probing proteins and lipids, respectively (B, D). Using FEL instead of QCL mid-IR radiation increased the field of view from 45 μm to more than 200 μm diameter.

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Session 4b:

Lasers for imaging & diagnosing life

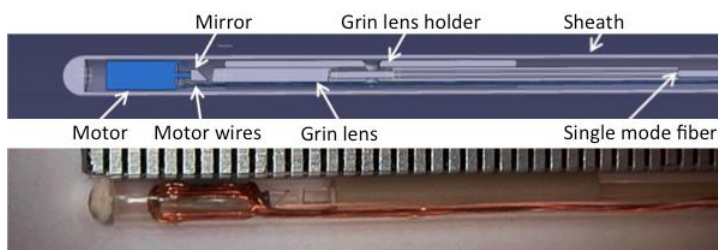
Immuno-OCT: Structural and molecular sensitive imaging in vivo at unprecedented resolution

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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, 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.



Schematic and actual picture of a motorized catheter with an outer diameter of 1.35 mm using a single mode fiber (SMF). Tick marks: 0.5 mm. The SMF remains stationary, the micromotor at the tip rotates a mirror at 45 degrees that reflects light through the transparent sheath onto the tissue.

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Session 5:

Lasers and laser-based instruments for the future

Laser Drivers for Inertial Confinement Fusion

Mariastefania De Vido, Paul Mason, Robbie Scott, Thomas Butcher, Cristina Hernandez-Gomez, John L. Collier¹

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The recent demonstration of target net gain in fusion experiments at the National Ignition Facility (NIF) [1] has marked a paradigm shift for laser-driven fusion research and for the development of future sustainable energy sources.

The realisation of power plants based on inertial confinement fusion (ICF) relies on the development of several key technologies, including new generation high pulse energy lasers operating at high pulse rate. The experiments at NIF have been performed using flash-lamp pumped glass lasers [2]. This technology is intrinsically limited in terms of wall-plug efficiency and pulse rate and is not a practical route for commercially viable fusion power plants.

This talk will present an overview of the main proposed ICF schemes, review required laser operational parameters and describe possible technological pathways for the realisation of fusion drivers for commercial power plants. The talk will conclude with a brief overview of the aims of the UPLIFT project [3], aimed at developing key technologies for laser-driven fusion, which has recently commenced at the STFC Central Laser Facility.

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Session 5:

Lasers and laser-based instruments for the future

Manipulation of laser-based secondary sources for enhanced EUV and x-rays

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Laser-based secondary sources of radiation in the soft X-ray and EUV range have the potential for imaging at the smallest spatial and temporal scales, given their wavelength range and ultrashort duration (fs or under). Recently novel degrees of freedom of light beam manipulation have been extended into the high intensity regime, to enhance their emissivity or expand their capability. We have used these pulse shaping techniques to generate coherent EUV sources, where High Harmonics from laser-gas interaction are seen to reproduce IR wavefront shaping and can generate light tubes with Orbital Angular Momentum using EUV optics. At close to relativistic intensities, our simulations show that the use of structured light pulses, coupling exotic polarisations and plasmas, also leads to improved features of the plasma-based X-ray sources.

Exhibition

Amplitude

Amplitude is an international company, with headquarters near Bordeaux (France) who manufactures a wide range of femtosecond and nanosecond laser systems for state-of-the-art applications in industry and medicine, as well as advanced laser solutions for cutting-edge scientific research.

www.amplitude-laser.com



CRYTUR

CRYTUR is the first-class provider of integrated optoelectronic solutions. High-tech production includes optical material manufacturing, laser crystal growth, optical polishing and coating, extensive high-precision CNC workshop and clean room assembly resulting in complex laser products and devices.

www.crytur.com



Fluence Technology

Fluence Technology is a manufacturer of femtosecond laser solutions with unique all-fiber technology. The company offers robust and stable industrial-grade femtosecond lasers that are immune to misalignment and feature a novel all-fiber oscillator for a robust, reliable package.

<https://fluence.technology/>



Exhibition

FYLA

We create and commercialize laser technology by joining singularity, quality and profitability for our clients and stakeholders, pursuing to lead the industry transformation towards photonics as a lever for the development of new sectors and new applications.



<https://fyla.com>

iLOF

iLoF is a deep tech company pioneering a breakthrough AI-powered Photonics platform to accelerate the future of personalized drug discovery and development. We're collecting massive amounts of data to build a digital library of biomarkers and biological profiles, aiming to get life-saving personalized treatments to patients faster.



<https://ilof.tech>

LaserLeap Technologies

LaserLeap Technologies is a biotechnology company specializing in dermocosmetics and photomedicine. Our flagship patent technology, known as Piezoporation, involves the delivery of high-intensity, high-frequency photoacoustic waves to the skin, thereby enhancing the penetration of active molecules.



www.laserleap.com

Exhibition

Lasing

Lasing, a Spanish company, has been distributing high-tech instrumentation and photonics since 1980, with excellent technical support. Their product portfolio comprises customizable laser processing systems for manufacturing, photovoltaic, semiconductor, automotive, aerospace, and industrial research.



www.lasing.com

Sarspec

Sarspec is an innovative Portuguese company in the field of fiber-optic spectroscopy in the UV-Vis-NIR range, from 185 to 2400 nm. Its portfolio includes a large variety of solutions (instrumentation and software) for application within the research and science, food and agriculture, and industrial and biomedical areas.



www.sarspec.com

Sphere Ultrafast Photonics

Sphere Ultrafast Photonics is devoted to world-class ultrafast pulsed laser solutions, providing products that highly improve the performance of femtosecond laser applications. Dispersion Scan is Sphere's core technology, a unique technique for measuring the electric field of ultrashort laser pulses



www.sphere-photonics.com

Access opportunities for international researchers from academia and industry

Lasers4EU

The successor of the Laserlab-Europe project will start 1 October 2024, ensuring that users can apply for transnational access projects on a large variety of scientific topics during the next five years. One of Lasers4EU's main objectives is to provide coordinated access to high-quality services based on a coherent and comprehensive consortium of 27 leading European laser installations offering to users from academia as well as from industry cutting-edge performances at the forefront of laser technologies. Lasers4EU also aims at structuring the European landscape of laser Research Infrastructure, and to increase European human resources in the field of laser science.

www.lasers4.eu

ReMade@ARI

Acknowledging the urgent need for a transition to a circular economy, the ReMade@ARI project brings together the large European analytical research infrastructures, featuring a central hub for free access to over 50 cutting-edge facilities to advance materials development for a circular economy. Tailored access routes are offered for academia, SMEs and large industry. Comprehensive support throughout the entire lifespan of a user project, which requires the utilization of at least two different analytical techniques, is provided by a team of 20 junior scientists.



www.remade-project.eu

RIANA

We offer free access to Europe's leading research infrastructures in nanoscience & nanotechnology. Customised and efficient access to 69 infrastructures is coordinated via a single-entry point and enabled through comprehensive science and innovation support by dedicated RIANA staff.

The involved networks Laserlab-Europe, LEAPS, e-DREAM, RADIATE, LENS, EuroNanoLab, and EUSMI cover the most advanced techniques for synthesis, nanofabrication, processing, characterization, analytics, as well as computation to enable users to generate the greatest impact.



www.riana-project.eu

Organised by

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About Laserlab-Europe

Laserlab-Europe, the Integrated Initiative of European Laser Research Infrastructures, understands itself as the central place in Europe where new developments in laser research take place in a flexible and co-ordinated fashion beyond the potential of a national scale. The Consortium currently brings together 35 leading organisations in laser-based interdisciplinary research from 18 countries. Its main objectives are to maintain a sustainable interdisciplinary network of European national laboratories; to strengthen the European leading role in laser research through Joint Research Activities; and to offer access to state-of-the-art laser research facilities to researchers from all fields of science and from any laboratory in order to perform world-class research.



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