ELISS 2024
Extreme Light Infrastructure Summer School

ELISS 2024
Book of Abstracts

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Lectures

WELCOME

10:00 - 12:40

Chair: Dimitris Charalambidis

MONDAY – 2 SEPT. 2024

Welcome speech

Gábor Szabó

ELI ALPS Facility, The Extreme Light Infrastructure ERIC, Szeged, Hungary

ELI ERIC: Development of a large scale laser facility

Andrew Harrison

ELI ERIC

The ELI ERIC (Extreme Light Infrastructure) is one of the largest European research projects focused on the development of ultra-high-power lasers. The aim of the project is to support research in materials science, biology, plasma physics, atomic physics, and other fields using world-class laser facilities. ELI has three main centers: in Szeged (attosecond laser research), in Prague (high-energy laser beams), and in Magurele (nuclear physics). The project is open to users, aiming to democratize science by providing access to high-performance lasers.

Attosecond science and technology at ELI ALPS

Subhendu Kahaly

ELI ALPS Facility, The Extreme Light Infrastructure ERIC, Szeged, Hungary

The advent of coherent attosecond XUV sources, which represent the shortest electromagnetic pulses generated in a controlled laboratory environment, has enabled unparalleled spatio-temporal resolution in the study of ultrafast photonic processes [1,2]. The creation and refinement of these sources rely on interactions spanning a broad spectrum of laser-matter parameters [3,4]. These pulses find applications across all four states of matter—gas, liquid, solid, and plasma—and are relevant to phenomena ranging from non-relativistic to relativistic, as well as from classical to quantum frameworks.

ELI ALPS, the Hungarian pillar of the Extreme Light Infrastructure project in Europe, capitalizes on these diverse scientific and technological advancements. It features cutting-edge high repetition rate lasers that drive advanced beamlines for generating secondary sources of light and particles [5,6]. The intricacy of the multi-parameter laser-matter interaction landscape requires optimal and innovative experimental approaches [7,8,9,10] to achieve the production of brighter and shorter attosecond pulses. This, in turn, necessitates a deep understanding of the competing high-harmonic generation processes.

In this talk, I will provide an overview of ELI ALPS, highlighting our unique capabilities and exploring the potential applications and scientific opportunities they offer.

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ELI Beamlines: the high-energy, high-average power pillar of the Extreme Light Infrastructure

Jakob Andreasson

ELI Beamlines Facility, The Extreme Light Infrastructure ERIC,
Dolní Břežany, Czech Republic

The ELI Beamlines Facility is a pillar of the ELI (Extreme Light Infrastructure) ERIC pan- European Research Infrastructure hosting four cutting edge high-peak, high-average power femtosecond laser systems and, in addition, offers a unique combination of primary (lasers up to 10 PW peak power) and secondary (high-energy particles and X-rays) sources to the international user community. Currently, several beamlines are operational and being upgraded to reach their full performances, while others are in their commissioning phase.

Laser-driven particle accelerators have gained interest in recent years thanks to their versatility and innovative features. This interest has pushed forward the development of beamlines where users can exploit the unique parameters (e.g. ultrashort bunch duration and ultrahigh dose rate) of laser-driven particle (ion and electron) and radiation (XUV to gamma-ray) sources for a wide range of applications, including pump-probe capabilities for high energy density physics and time-resolved studies of sample systems ranging from isolated atoms, through molecules and clusters to the solid state.

The current performance of particle and radiation sources available at the ELI Beamlines user facility will be briefly presented and discussed along with their potential use for multidisciplinary applications. The high repetition rate capability of the available primary and secondary sources will be highlighted in combination with a range of advanced target delivery solutions and diagnostics in operation in extreme laser-plasma conditions (>10^{21} W/cm^2 at >1 Hz and >5×10^{18} W/cm^2 at 1 kHz). The potential combination of optical, X-ray, and particle beams for user experiments related to inertial confinement fusion and shock physics will also be introduced in relation to the availability of a unique kJ-class, nanosecond laser beam operating at unprecedented repetition rate (~1 shot/min) and offering unique temporal and spectral shaping capabilities to users.

ELI-NP status and challenges

Victor Malka

ELI-NP, Măgurele, Romania
Department of Physics of Complex Systems, Weizmann Institute of Science,
Rehovot, Israel

In addition to the dual 10 PW that is the most powerful laser in the world, ELI-NP is delivering to the user community access to the many experimental areas where the versatile laser can deliver its energy with a wide range of parameters. This unique European Facility will permit to breakthrough discoveries in nuclear, high field and plasma domains together with societal applications in medicine, biology and security.

Session 1
GAS PHASE ATTOSCIENCE

13:30 - 16:30

Chair: Jakob Andreasson

MONDAY – 2 SEPT. 2024

Attochemistry: chemistry at the attosecond time scale

Fernando Martín

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Instituto Madrileño de Estudios Avanzados en Nanociencia (IMDEA-Nano), Cantoblanco, Madrid, Spain

With the advent of attosecond light pulses at the dawn of the twenty first century, access to the time scale of electronic motion, i.e. the ultimate time scale responsible for chemical transformations, was finally at our reach. Since the first attosecond pump-probe experiments performed in molecules [1,2], the field has grown exponentially, leading to a discipline that we call attochemistry [3]. As a result, it is nowadays possible to follow in real time the motion of the "fast" electronic motion in molecules, mostly in the gas phase, and understand how this motion affects the "slower" motion of atomic nuclei and vice versa. There are, however, new scenarios [4] that will allow one to extend the range of applications to more complex molecular systems, including the condensed phase, and to overcome some of the limitations of current attosecond technologies [5-9], such as the low intensity of attosecond pulses produced by high harmonic generation, the impossibility to generate such pulses in the visible and UV spectral regions to avoid molecular ionization or the difficulties to combine them with truly imaging methods for direct time-resolved observations of the electron density without the need for reconstruction from measured photoelectron, photoion or transient absorption spectra.

In this talk, I will describe current experimental and theoretical efforts aiming at overcoming the above-mentioned limitations, thus giving attochemistry the necessary push to investigate problems of real chemical interest.

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Attosecond physics in model and complex (bio-)molecules

Franck Lépine

University of Lyon, Claude Bernard Lyon 1 University, CNRS, The Institute of Light and Matter, Villeurbanne, France

Attosecond Science has provided new means to investigate molecular processes on ultrafast timescales.Since the first pump-probe experiments performed in molecules[1], new technics have been developed to address emerging questions[2] and to investigate increasingly complex systems such as polyatomics[3] or amino-acids[4]. Nowadays, it became possible to perform time resolved experiments using ultrashort XUV/X-ray pulses combined with transient absorption, angularly resolved photoelectron spectroscopy, coincidence, mass-spectrometry etc... with these tools, processes such as hole migration, ICD, non-adiabatic dynamics, ionization delays fragmentation, structural changes can be observed with unprecedent time precision. With the improvement of light sources and spectroscopic methods, experiments addressing the dynamics of quantum properties in few-body systems can be probed, at the same time much larger systems[5,6,7], potentially of chemical and biological interest such as a protein can be investigated[8,9,10], offering new perspectives in terms of interdisciplinary.

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Quantum coherence and entanglement in attosecond molecular photoionization

Marco Ruberti

Imperial College London, Physics Department, Blackett Laboratory, London, United Kingdom
Max-Born-Institute, Berlin, Germany

Attosecond science enables the study of ultrafast electron dynamics in matter upon photoexcitation and photoionization. In the photoionization scenario, an atomic or molecular quantum system breaks up into a pair of quantum-mechanically entangled subsystems: the emitted photoelectron and its parent ion. Two key concepts characterize the triggered ultrafast many-electron dynamics: quantum coherence[1] and quantum entanglement: the former underpins the few-femtosecond charge dynamics in molecules and the ensuing photochemical transformation; the latter limits the coherence that can be observed within each subsystem when interrogated individually by probe measurements.

In my lecture I will discuss these key concepts and present two pump-probe studies of ultrafast quantum electronic coherences in molecules. These include (i) a theoretical time-resolved study of X-ray attosecond transient absorption spectroscopy in photoionized pyrazine[2]; (ii) a combined experimental-theoretical study of electronic quantum coherence in molecular glycine[3], where few-femtosecond X-ray pulses are used to trigger coherent dynamics in the glycine cation and probe it by resonant X-ray absorption and sequential double photoionization. The results provide a direct support for the existence long-lived electronic coherence up to 25 femtoseconds[3]. In both works[2,3], simulations are performed using the time-dependent B-spline RCS-ADC[4] *ab initio* method for many-electron photoionization dynamics in polyatomic molecules. Finally, I will present novel results from a recent work where we designed theoretically and modelled numerically a direct probe of quantum entanglement in attosecond molecular photoionization in the form of a Bell test[5]. This key theoretical result paves the way to the direct observation of quantum correlations in the context of ultrafast photoionization of many-electron systems, where they have thus far remained much more elusive than quantum coherence.

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Session 2
ACCELERATION – PLASMA

09:00 - 12:00

Chair: Christos Kamperidis

A brief history of laser plasma accelerators

Victor Malka
Weizmann Institute of Science, Rehovot, Israel
ELI-NP, Măgurele, Romania

Laser Plasma Accelerators (LPA) are changing the scientific and societal landscape. Opening new hopes for high energy physics, offering alternative to synchrotron light sources with the recent demonstration with LPA's based Free Electron Radiation, and delivering particle and radiation beams for medical and security applications, they are among the most innovative tools of modern sciences. I'll explain the main involved concepts, and why these wonderful machines rely on our ability to control finely the electrons motion with intense laser pulses. I'll show how the electrons collective manipulation permits to produce giant electric fields of value in the 100 GV/m exceeding by 3 orders of magnitude or more the ones used in current machines. This control is crucial for electrons injection that is essential for delivering stable ultra-short and ultra-bright energetic particle or radiation beams. To illustrate the beauty of laser plasma accelerators I will show some concepts we recently demonstrated that allow these controls for beams improvements. Finally, I will discuss on the next challenges together with new ideas that will be tested in the next future.

Development of applications for laser plasma accelerators

Olle Lundh
Department of Physics, Lund University, Lund, Sweden

Laser technology is advancing rapidly, with high-power lasers essential for plasma acceleration now available commercially from multiple providers. These lasers come in compact setups, making them ideal for space-constrained environments such as industrial or hospital settings. Furthermore, relativistic laser-plasma interactions open new possibilities for tunability and precise control. Now is the ideal moment to pinpoint key areas where compact laser-plasma accelerators can significantly impact science and society.

We explore the potential of laser-accelerated particle beams in cancer radiotherapy, focusing on the precise treatment of deep-seated tumours to potentially enhance treatment outcomes. We also investigate various methods for generating XUV and X-ray radiation and their application in studying the rapid evolution of microscopic flows, compounds, and structures. These advancements hold promise for significant insights across a wide range of fields, including medical and biological applications, military and defence technologies, industrial processes, and condensed matter and high-energy density science.

Laser-driven proton acceleration – schemes and diagnostics

Karl Zeil
Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

Ion acceleration via compact laser-plasma sources holds significant potential for applications ranging from medical treatments to fusion research. Achieving the desired beam quality requires a deep understanding and precise control of the laser-plasma interaction process. This presentation will summarize various acceleration schemes across different target density ranges, with a particular focus on the promising regime of relativistically induced transparency (RIT).

Recent experiments conducted with the ultra-short pulse PW laser system, Draco, have recorded proton energies exceeding 100 MeV [Ziegler, T. et al.: Nat. Phys. (2024)], highlighting the critical importance of the transparency onset time in optimizing beam parameters and enhancing the robustness of the process.

The presentation will also review typical experimental diagnostics, with a special emphasis on combining particle and laser diagnostics to explore the correlation between transparency onset and acceleration performance—a particularly interesting area of research.

Our recent investigations into the spectral components of transmission and emission from the laser-plasma interaction will be detailed. We will present an example approach involving spectral interferometry, using the unperturbed laser beam as a reference, and correlating these findings with proton acceleration performance. Such methodologies will advance our understanding of ion acceleration mechanisms, contributing to the optimization of beam quality parameters.

Session 3
QED – NP

13:30 - 16:30

Chair: Paolo Tomassini

TUESDAY – 3 SEPT. 2024

Quantum electrodynamics with Intense background fields

Felix Karbstein

Helmholtz Institute, Jena, Germany

In this talk, I will provide a introduction into quantum electrodynamics (QED) in the presence of strong external electromagnetic fields. I will highlight the differences from standard QED, introduce and discuss the relevant parameters of the theory, and detail why strong field QED amounts to a both very interesting and challenging research area. The main intention of my talk is to provide the audience with a general idea of the relevant concepts and research questions in QED with intense background fields.

Overview of inertial fusion energy

David Blackman

ELI Beamlines Facility, The Extreme Light Infrastructure ERIC, Dolní Břežany, Czech Republic

The idea that energy can be generated from the nuclear fusion of light nuclei has received a boost thanks to successful experiments at the National Ignition Facility in the United States and using separate technology at the Joint European Torus in the UK. This talk will present an incomplete outline of the technological challenges in constructing an inertial fusion energy power plant. It will first describe what types of fusion reactions are desirable and so the fuel, and temperature and density requirements for them to occur. A brief description of magnetic confinement fusion follows and several notable projects using this idea are described. A more in depth description of inertial confinement fusion experiments is then provided and an introduction to inertial fusion energy, along with alternative ignition schemes, is presented. The major technological developments required to construct an inertial fusion power plant are then described including material challenges, reactor wall designs, fuel cycles, and target construction and delivery. Finally a description of some of the research that can be, and is, performed at the ELI facilities will be given.

Probing strong-field QED with laser-based experiments

Sebastian Meuren

LULI, CNRS, CEA, Sorbonne Université, École Polytechnique, Institut Polytechnique, Palaiseau, France

QED is often considered the most successful theory in physics, as it permits extremely precise predictions in the perturbative regime. In this tutorial talk, we will review experiments that focus coherent laser light into such small space-time volumes that a charged particle passing through the resulting photon density interacts with much more than just one photon, implying that conventional scattering theory is breaking down and that the particle is probing the collective electromagnetic field of the laser. If the charge experiences an electric field that is comparable to or larger than the so-called QED critical ("Schwinger") field in its own rest frame, the domain of Strong-Field QED is entered [1,2].

This talk will focus on electron-laser collisions which are currently being used in various experiments to probe SFQED, such as E-320 at SLAC/FACET-II [3], LUXE [4], and several LWFA-based campaigns (see, e.g.[5]). To this end, the theoretical description of electron and photon beams will be reviewed with a focus on the Gaussian approximation. In particular, we will discuss the challenges of compressing and properly synchronizing these beams in both space and time. Furthermore, diagnostics are covered that are capable of delivering shot-to-shot feedback about the actual collision conditions.

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Session 4
QUANTUMATTO

9:00 - 12:00

Chair: Péter Földi

WEDNESDAY – 4 SEPT. 2024

Control of attosecond entanglement and coherence

Marc Vrakking

Max Born Institute (MBI), Berlin, Germany

Attosecond science is a branch of ultrafast laser physics that aims to investigate and possibly control electronic motion on its natural timescale by means of pump-probe experiments. Attosecond pulses are formed by the process of high-harmonic generation. Their generation and characterization were recently recognized by the 2023 Physics Nobel Prize, awarded to Anne L'Huillier, Pierre Agostini and Ferenc Krausz.

My tutorial will consist of two parts, one concerned with the science that is addressed by attosecond laser pulses, and one concerned with recent developments in attosecond technology. In the first part, I will discuss experimental and numerical work demonstrating the role of ion-photoelectron entanglement in attosecond pump-probe experiments, by taking as an example the vibrational and electronic wave packet dynamics that is induced in H2+ cations upon ionization of H2 by an attosecond laser pulse [1-4]. In the second part, I will show how we have recently achieved the longtime dream of performing all-attosecond pump-probe experiments, where attosecond pulses are used both as the pump and the probe in the experiment [5, 6]. I will present our first all-attosecond transient absorption spectroscopy (AATAS) experiments [7].

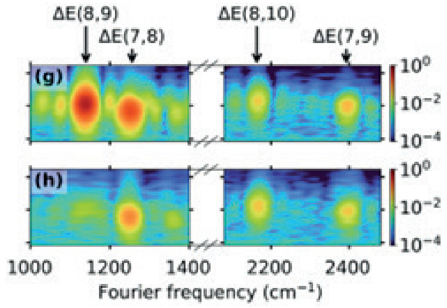

Figure 1.
Fourier Transform Power spectra revealing vibrational coherences that occur in a pump-probe experiment on H2 molecules. The upper and lower data set was recorded using two different delays between the attosecond pulse trains that were used to ionize the molecule. The absence of a number of vibrational coherences in the lower figure is due to ion-photoelectron entanglement.

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Generation of optical Schrödinger "cat" using intense laser-matter interactions and applications in non-linear optics

Paraskevas Tzallas

Foundation for Research and Technology-Hellas, Institute of Electronic Structure & Laser, Heraklion (Crete), Greece

The interaction of matter with intense laser pulses leads to high harmonic generation (HHG), where the low frequency photons of a driving laser field are converted into photons of higher frequencies. This process has been used in numerous fascinating achievements in atomic, molecular and optical physics, and is at the core of attosecond science [1]. Until recently, the process has been successfully described by classical or semi-classical strong-field approximations [2], treating the electromagnetic field classically and ignoring its quantum nature. In our recent theoretical and experimental investigations [3-7], conducted using fully quantized approaches in intense laser-atom interactions, we have shown how quantum operations in the high harmonic generation (HHG) process, can lead to the generation of optical Schrödinger "cat" states and entangled light states with controllable quantum features.

Here, following the introduction of the operation principle of the approach, I will present our recent findings on the generation of high photon number optical "cat" states and their application in nonlinear optics [9]. The findings mark the initiation of a diverse range of new investigations and developments. We aspire to leverage strongly laser-driven materials for the development of a new class of non-classical and massively entangled states [5, 7, 10] for applications in quantum technologies [11].

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Exploring molecular dynamics with ultrafast X-rays

Markus Gühr
DESY and Physical Chemistry, University of Hamburg, Germany

In this tutorial, I will introduce the fundamental molecular behaviors that govern the conversion of photon energy into various molecular degrees of freedom, such as energetic bonds and heat. I will then demonstrate how ultrafast X-ray pulses serve as exceptional tools for investigating the electronic and structural changes that drive energy conversion.

To probe the electronic degrees of freedom within a molecule, X-ray absorption and X-ray photoemission spectroscopy offer ideal methodologies. For tracking geometric changes, I will introduce Coulomb Explosion Imaging. When combined, these techniques provide an almost complete molecular "movie," capturing the intricate dynamics at play.

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Session 5
LASERS

13:30 - 16:30

Chair: Ádám Börzsönyi

Introduction to high power lasers

Leonida A. Gizzi
Istituto Nazionale di Ottica, CNR, Pisa, Italy

Laser-driven plasma acceleration is now finally entering the transition phase from lab demonstration to practical exploitation, to deliver particle accelerators for medical applications or light source as user facilities based on this novel technology. At the same time, Inertial Fusion Energy is now seeking new laser schemes to deliver extraordinary performaces in terms of bandwidth, average power and efficiency, as needed to envision future IFE reactors. These circumstances are motivating an extraordinary wave of laser developments of high-power lasers.

Indeed, a number of laser architectures capable of delivering ultrashort, PW-scale laser pulses at high repetition rate, from tens of Hz to kHz and beyond, with high average power, including Ti:Sa and OPCPA with diode-pumped pump lasers, are being explored and developed and some are already approaching the specs required for the first stage of operation of laser-driven light sources or medical accelerators, with significant industrial engagement.

In the longer term, technology issues remain and should be tackled using an application-oriented approach, focusing on improved stability, reliability and energy and cost affordability. In view of these issues, new materials and architectures are being proposed and tested.

An introduction to high-power lasers will be given in this presentation, looking into the main features of the most advanced laser systems and discussing the properties of amplifying lasing media and their impact on the scalability, in terms of peak and average power and repetition rate and, ultimately energy efficiency.

Introduction to Laser Physics

Robert Boge
ELI Beamlines Facility, The Extreme Light Infrastructure ERIC,
Dolní Břežany, Czech Republic

In this lecture, we will explore the fundamentals of laser physics. Beginning with the principle of amplification through stimulated emission, we will examine oscillators, ultrashort pulse generation, dispersion, and temporal control. Additionally, we will review various amplifier types and geometries. Finally, we will discuss how these components are integrated to create large-scale laser amplifier systems.

10 PW laser system at ELI-NP

Ioan Dancus
ELI-NP, Măgurele, Romania

The 10 PW High Power Laser System (HPLS) at Extreme Light Infrastructure – Nuclear Physics (ELI-NP) is a dual arm laser system capable of delivering peak power laser pulses of 10 PW at 1 shot/minute repetition rate, 1 PW at 1 Hz repetition rate or 100 TW at 10 Hz repetition rate. The pulses from both arms are distributed to dedicated experimental areas: E4 for 2 x 100 TW, E5 for 2 x 1 PW and E1-E6 for the 2 x 10 PW [1]. Using the HPLS, we demonstrated the propagation of 10 PW peak power pulses to an experimental area [2].

From the beginning of 2020 laser pulses at nominal power, 100 TW and 1 PW respectively, were sent towards E4 and E5 areas for commissioning experiments. The first 10 PW pulses on target were shot in April 2023 in the experimental area E1. In this period procedures to tune the laser parameters are developed, adapted and implemented in the HPLS. Figure 1 shows the energy histogram at the 10 PW output in August 2024, showing that more than 400 shots were fired at an energy compatible with 10 PW peak power.

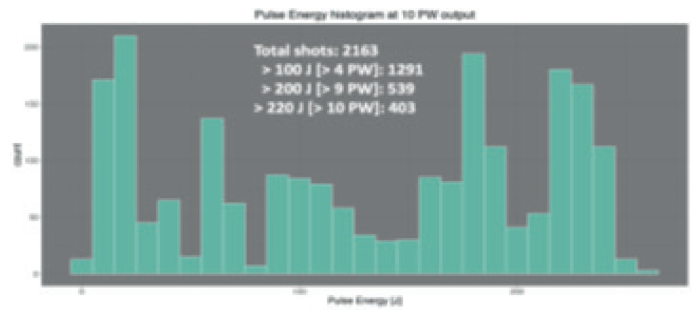

Figure 1.
The Histogram of the pulse energy delivered at the 10 PW output of the HPLS at ELI-NP shows that more than 400 shots were fired at energies compatible with 10 PW peak power.

In this short course, we will show some of the laser parameters obtained in the experimental areas, the tuning procedures used to optimize them, and our efforts towards proper laser metrology on target. We will also show recent work and results in improving the temporal contrast. These methods rely strongly on the collaboration of the laser operation and experimental teams.

In the presentation, we will also show statistical data on beam delivery with typical laser parameters that can be expected by the users.

Acknowledgements
We gratefully acknowledge the contribution of the entire ELI-NP and Thales teams and collaborators. The picosecond contrast improvement activities are supported by a collaboration between ELI-NP, Thales and Marvel Fusion.

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Session 6
ATTO-, XUV- AND X-RAY SOURCES

09:00 - 12:00

Chair: Zsolt Divéki

THURSDAY – 5 SEPT. 2024

Science of attosecond pulses

Katalin Varjú

ELI ALPS Facility, The Extreme Light Infrastructure ERIC, Szeged, Hungary

The 2023 Nobel Prize in Physics was awarded for the study of the movement of electrons in atoms, molecules and matter in the condensed phase by means of attosecond spectroscopy. In this talk I will review the history - via science advancements - of the evolution of this research field that led to the birth of attoscience. I will also give a brief summary of the relevance of this Prize for ELI ALPS.

When an intense laser pulse interacts with a gas of atoms, high-order harmonics are generated. In the time domain, this radiation may form a single pulse or a train of extremely short light pulses, of the order of 100 attoseconds. The production and tailoring of these attosecond pulses relies on microscopic and macroscopic aspects of the gas - laser interaction. Attosecond pulses allow the study of the dynamics of electrons using advanced pump-probe techniques.

Physics of plasma mirrors in ultraintense laser fields

Fabien Quéré

Pasqal, Massy, France

When an intense laser pulse (I>1015 W/cm2) impinges a solid target, it creates a dense plasma at its surface. During an ultrashort laser pulse—typically below 1 ps—this plasma only expands by a small fraction of the light wavelength, and keeps an almost step-like interface with vacuum: it thus behaves as a high-flatness mirror, called a plasma mirror, which can be exposed to extremely high laser intensities. The response of the plasma to the field then becomes highly non-linear, and high-order harmonics of the incident laser frequency are observed in the beam reflected by such a plasma mirror. Such processes provide a way to produce high-energy XUV femtosecond and attosecond pulses from ultrafast ultraintense lasers, but also high-charge bunches of relativistic electrons.

This course will focus on the basic physics of plasma mirrors, and on the experimental and numerical tools used for this type of experiments. In conclusion, we will discuss the perspectives offered by this type of interaction with the recent advent of femtosecond Petawatt lasers, especially for the experimental investigation of non-linear QED effects, such as pair creation by light in vacuum - the so-called Schwinger effect.

Development of table-top XUV and soft-X sources based on microfluidic devices

Anna Gabriella Ciriolo

National Research Council (CNR), Institute for Photonics and Nanotechnologies, Milano, Italy
Politecnico di Milano, Physics Department, Milano, Italy
National Research Council (CNR), Institute for Photonics and Nanotechnologies, Padua, Italy

The development of table-top optical sources of coherent eXtreme UltraViolet (XUV) and Soft-X ray radiation based on the High-order Harmonic Generation (HHG) process has been boosted by the advances of ultrafast laser technologies. The successful application of HHG sources to ultrafast spectroscopy and X-ray science has been widely demonstrated. However, its exploitation is significantly hindered, even today, by the technological complexity of the required setups and the low generation efficiency, particularly when moving towards higher photon energies.

This limit underlies the compelling challenges of exploring novel approaches to enhancing the application perspectives of HHG-based sources.

Here, we report on the development of innovative microfluidic platforms for XUV generation and manipulation, fully integrated inside a glass device and fabricated by Femtosecond Laser Micro-machining (FLM). We show that the use of microfluidic systems offers the unique advantage of enabling accurate control and shaping of the harmonic generation conditions. In particular, by propagating ultrashort laser pulses inside the microfluidic devices, we demonstrate high photon fluxes and broadband harmonics spectra, up to 200 eV, from tailored gas media.

Furthermore, the integrated microfluidic approach allows the control of the spatial properties of the HHG beam through the direct manipulation of the waveguide's modal characteristics, making it possible to generate structured EUV/Soft-X light for application to ultrafast spectroscopy and high-resolution imaging.

Following the route traced by microfluidics, we foresee the potential for integrating multiple optical functionalities within a single monolithic glass, thus paving the way to a novel generation of palm-top-size X-ray experimental stations.

Session 7
CONDENSED PHASE ATTOSCIENCE

13:30 - 16:30

Chair: László Óvári

Time-resolved photoemission spectroscopy – An ultrafast camera to image charge and spin carrier dynamics in condensed matter

Benjamin Stadtmüller

Institute of Physics, Augsburg University, Germany

Understanding the evolution of charge and spin carriers on their intrinsic atto- to picosecond timescales is crucial for many fundamental and application-oriented phenomena in condensed matter systems. Charge and spin carriers dominate the light-matter interaction in any material and thus determine the efficiency of optical-to-electrical energy conversion in photovoltaic devices or set limits on the speed of manipulation of materials by ultrashort light pulses. In addition, the ultrafast carrier dynamics is responsible for the speed and efficiency of modern information and quantum technologies, since charge and spin carriers are the primary information carriers in such applications. Therefore, it is of utmost importance to image the ultrafast dynamics of optically excited spin and charge carriers in real-time and to reveal their relationship to the fundamental interactions between the different degrees of freedom in condensed matter systems.

In this contribution, I will introduce the experimental method of time-resolved photoemission as a highly versatile tool to image the ultrafast spin and carrier dynamics at surfaces, interfaces, and bulk materials with temporal resolution down to the attosecond time regime. This is made possible by combining ultrafast photon sources for the extreme UV range with the latest technological advances in electron spectrometer technology. This allows one to image the spin, momentum, energy and spatially resolved photoemission yield in single experiments (see Fig. 1).

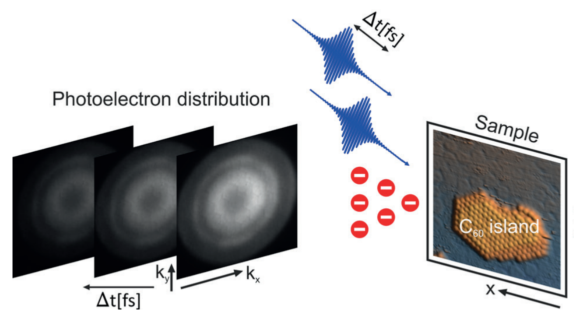

Figure 1. Schematic representation of a time-resolved photoelectron spectroscopy experiment: A fs pump pulse excites electrons in the material while a second fs probe pulse creates photoelectrons that are detected as function of the pump-probe delay. microscopy experiment

To this end, I will first discuss the current understanding of ultrafast charge and spin carrier dynamics in condensed matter and highlight challenges and opportunities for studying such dynamics with ultrafast spectroscopy. I will then turn to the fundamentals of ultrafast photoemission on pico- to attosecond timescales. In particular, I will discuss both the conceptual and technological realization of this method and illustrate its potential and challenges by presenting recent examples and breakthroughs from the fields of (molecular) interface science, ultrafast magnetism, and attosecond spectroscopy. Finally, I will relate these studies to the current activities at the ELI ALPS research facility.

Attosecond physics with synthesized light

Eleftherios Goulielmakis

University of Rostock, Germany

Relaxation, band filling, and screening effects in the transient dielectric function of germanium determined with femtosecond ellipsometry

Stefan Zollner

Department of Physics, New Mexico State University, Las Cruces, NM, USA

Traditional femtosecond pump-probe transmission and reflection measurements only provide qualitative insights into the optical constants (complex refractive index, absorption coefficient, dielectric function) of highly excited solids. This work reports a femtosecond pump-probe ellipsometry experiment available to users at ELI Beamlines in Dolni Brezany, Czech Republic, which provides quantitative results for the transient dielectric function.

This lecture will introduce the spectroscopic ellipsometry technique, its experimental implementation at ELI Beamlines, and results for germanium, an important material for electronic and photonic applications. Within the duration of the 35 fs pump pulse, photoexcited electron-hole pairs quickly thermalize near the Gamma-point of the Brillouin zone and then scatter to the satellite valleys at the L- and X-points. This hot electron plasma cools by intervalley phonon scattering and electrons eventually accumulate in the L-valley. We calculate the time-dependent dielectric function near the E1 and E1+Δ1 transitions using quantum statistics and consider bleaching of the absorption due to band filling, but this only partially explains the experimental data. We also need to consider the screening of the excitonic (Sommerfeld) enhancement of the optical absorption at high electron densities.

This work was carried out in collaboration with Carola Emminger, Carlos A. Armenta (NMSU), Shirly Espinoza, Mateusz Rebarz, Martin Zahradnik, Saul Vazquez-Miranda, Jakob Andreasson (ELI Beamlines), Steffen Richter, Oliver Herrfurth, Rüdiger Schmidt-Grund (Leipzig, Ilmenau). This work was supported by the US Air Force of Scientific Research (FA9550-20-1-0135, FA9550-24-1-0061).

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Posters

Aaron Peacock
King's College London, United Kingdom

The generation of intense, coherent XUV attosecond pulses through the process of high-harmonic generation (HHG) is an area of significant scientific interest with applications across various fields. However, a fundamental challenge lies in the relatively low brightness of the generated harmonic/XUV signal. While increasing the brightness by raising the driving field intensity is effective to some extent, it becomes limited by rapid ionisation of the medium at high intensities. To address this limitation, it has been shown that using a weak mid-IR field can mitigate the effects of ionisation on both the driving and harmonic fields through a process known as High order Frequency Mixing (HFM). We aim to numerically simulate this process by coupling the microscopic response of the medium to its macroscopic propagation, demonstrating the potential of HFM to enable the generation of brighter attosecond pulses.

Abdullah Abduljaleel
Humboldt University of Berlin, Germany

This thesis focuses on the optimization of high harmonic generation (HHG) using 800 nm and 400 nm driving laser beams, motivated by the 2023 Nobel Prize in Physics for attosecond pulses production. HHG experiments, essential for exploring ambiguous natural phenomena, face challenges in phase matching among propagation effects. Our research includes two experiments: the first with an 800 nm setup, investigating phase matching conditions across various pressures and driving pulse energies; the second with a new 400 nm setup, comparing it with the 800 nm source by varying group delay dispersion (GDD) and third-order dispersion (TOD) values. The results identified optimal phase matching conditions for both sources, showing that 400 nm light required lower pressures and produced less photon energy compared to 800 nm light. Overall, 800 nm sources provided higher photon energies and greater flexibility, aligning well with theoretical predictions.

Abhishek Panchal
CEA Paris-Saclay, France

Ultra-high dose rate effects from laser-driven electrons on Fricke dosimeter

Flash radiotherapy (FLASH-RT) is a relatively recent irradiation technology that involves the ultra-fast delivery of radiation treatment at dose-rates orders of magnitude higher than conventional RT. The main advantage of FLASH-RT is that it preserves the surrounding normal tissue while maintaining the same tumour control. Despite the underlying physical and biological mechanisms remaining unclear, FLASH-RT is currently recognized as one of the most promising breakthroughs in radiation oncology. Laser-driven particle sources are promising sources for FLASH-RT as they are able to deliver ultra-high dose-rate, because of their extreme short duration. However, novel dosimetry systems adapted to this particular irradiation modality need to be developed in order to translate FLASH-RT towards a routine clinical use. In this framework, we studied the Fricke dosimetry, also called ferrous sulphate dosimetry, which is sensitive to dose-rate effects [1].

Previous results [2] report a decrease of the Fe3+ yields with dose-rate of 108 Gy/s using ns electron beams produced by a conventional accelerator. We present here the results of using an even higher dose-rate electron beam exceeding 1010 Gy/s using a laser plasma accelerator.

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Alex Whitehead
ELI Beamlines Facility, The Extreme Light Infrastructure ERIC, Dolní Břežany, Czech Republic

A 100 TW DPSSL-OPCPA L2-DUHA laser system is under development at ELI-ERIC, with the goal to be the driver for the Laser Plasma Accelerator (LPA) of the LUIS-beamline, an under development incoherent setup at ELI-ERIC, aiming to get high-quality electron beam required for the LPA-based Free Electron Laser (FEL).

The L2-DUHA broadband front-end is seeded by a 2kHz Yb:YAG thin disk regenerative amplifier. It will provide a 1mJ near Infrared (NIR) beam for the high power OPCPA, which will be used as the driver for the laser-plasma accelerator in the LUIS-beamline. In addition, a 5mJ mid IR auxiliary beam for high harmonic generation is under development. Both outputs are generated via supercontinuum in YAG crystals, and are passing through pre-amplification OPA stages using Barium Borate (BBO) crystals.

In this poster, we present the first characterization of the L2-DUHA broadband front-end.

Alina Kaliuzhna
University of South Bohemia in České Budějovice, Czech Republic

Dual photosynthesis: Efficiency of photosynthetic pigments in extreme conditions

The recently discovered heterotrophic bacteria encode a fully functional bacteriochlorophyll-based photosynthetic apparatus alongside xanthorhodopsin with proton pump. The bacteria preferentially use one of the systems in certain conditions. While xanthorhodopsin is efficiently expressed at temperatures below 16ºC and in the presence of light, bacteriochlorophyll shows expression between 4 ºC and 22 ºC and only in dark conditions. This suggests that dual phototrophy may provide significant advantages, particularly in environments characterized by extreme light and temperature fluctuations.

Here we studied the excited state dynamics of the light-harvesting antenna-reaction center complex. The experiments were performed at varying temperatures and illumination to simulate varying environmental conditions. Next, the same series of experiments will be performed for the second photosynthetic complex - xanthorhodopsin with nostoxanthin antenna.

This comparative study will illustrate the differences in energy transfer and photoprotective mechanisms employed by the two distinct photosynthetic systems.

Andor Vancza
HUN-REN Wigner Research Centre for Physics, Hungary

In the past few decades, transition-metal complexes have been a topic of extensive research in an effort to find suitable candidates for potential applications as molecular switches, memory devices, or in light harvesting systems. While several individual studies exist already, revealing the effect of electron donating (ED) and withdrawing (EW) substituents on the ultrafast relaxation process of such compounds requires further systematic investigations.

In the present work we synthesized homoleptic and heteroleptic Fe(II)-bis-terpyridine complexes using ligand combinations of different ED/EW character and substituent position (4' and 5,5"). We carried out transient absorption measurements on our setup at Wigner RCP and at the ELI ALPS and ELI Beamlines facilities, determined the lifetimes of the high-spin (HS) state and attempted to relate these to the Hammett and Swain-Lupton substituent parameters. We propose a semi-quantitative formula to describe the correlation between these parameters and the HS lifetime for both substituent positions.

Andrei Giulesteanu
ELI-NP, Măgurele, Romania

In the past decades there has been a great interest in target fabrication of boron (B) and boron-based compounds, especially for proton-boron fusion with tokamaks or for laser driven fusion. In this poster it will be presented the state of the art on B target fabrication using bottom-up or top-up approaches and preliminary experimental data on boron-based targets fabrication. The targets were fabricated using a spin-coating method using solutions of dispersed B-nanoparticles on Si substrates. The samples were characterized using optical and electronic microscopy in order to understand the B distribution within the resulted spin coated layers. The results showed that the spin coated methd using nanoparticles leads to not homogeneous distributed B within the layers. Future experiments using physical methods (sputtering) will be performed in order to produce continous layers of B-based materials that can be used as targets for high power laser experiments.

Augustė Černeckytė
Center for Physical Sciences and Technology, Lithuania

Cost-effective few-cycle mJ-level laser at 1800–3000 nm based on OPCPA and rotational SRS in hydrogen

We demonstrate an affordable, compact, and easy-to-replicate mJ-level mid-IR laser based on fiber seed, hybrid chirped-pulse amplifier (CPA), grating compressor, supercontinuum generation, AOPDF, OPCPA, chirped-mirror compressor, and SRS-converter. A two-stage four-pass CPA based on Yb:YAG and Yb:LuAG rods ensured a gain of ~10 million times from a ~1 nJ seed. Pulses compressed to ~1.3 ps with energy ~10 mJ at 1030 nm were used to both excite supercontinuum at ~1050–2400 nm and pump OPCPA. Three degenerate OPCPA stages with BiBO crystals provided output pulses of ~2.5 mJ, ~25 fs at ~2150 nm after compression with a conversion efficiency of ~27% in the last stage. Further spectral expansion to ~3000 nm achieved using cascade rotational SRS in compressed hydrogen. This cost-effective architecture of mid-IR driving laser paves the way for THz and attosecond X-ray pulse generation, particle acceleration. It has already been tested for remote sensing of gases.

Carlos Miguel Garcia Rosas
Institut National de la Recherche Scientifique, Canada

In this work, we reveal the intricate interplay between two major nonlinear THz effects: intervalley scattering and impact ionization, generated by an intense few-cycle THz pulse in an undoped (100) indium antimonide semiconductor at room temperature. Our results show an initial transmission enhancement when increasing the peak electric field up to 91 kV/cm, followed by increased absorption for higher fields. Our analytical model explains that the THz strength of 91 kV/cm, is the critical field where bleaching of absorption (induced by intervalley scattering of electrons in the conduction band) is dominant below this field, whereas above it impact ionization starts to be the dominant energy loss mechanism. These experimental results match very well qualitatively and quantitatively with our developed theoretical model.

Cezara Rășinar
ELI-NP, Măgurele, Romania

A research program focused on Phase Contrast X-ray Imaging is being developed at ELI-NP, aiming to explore its potential in biomedical applications. A primary focus of this research will be to investigate ultrahigh-sensitivity X-ray grating interferometry techniques using laser-based X-ray sources. To further this objective, a 6-meter-long Talbot-Lau interferometer, in combination with a conventional X-ray tube, has been developed within the X-ray Imaging Laboratory (XIL). The phase-stepping method have been involved in the extraction of three images represented by attenuation, differential phase contrast, and dark-field contrast. Advanced image processing techniques have been integrated to enhance the visualization capabilities of phase-contrast imaging. In this regard, a fusion-based algorithm, that aims to merge the three acquired images, was applied to the images acquired, using a 5.66 m long Talbot-Lau Interferometer with an ultrahigh sensitivity of 0.84 μradians. The obtained results are quite promising, succeeding in providing complex information about the investigated tissue.

Dariusz Duszynski
Imperial College London, United Kingdom

The Cerberus laser at Imperial College London is being used to de-risk an upgrade to the high-contrast petawatt beamlines of AWE Aldermaston's Orion laser, due to their similar frontend architecture. Several schemes for frequency-doubling a high-power laser pulse are proposed: doubling pre-compression, post-compression in a thin (few mm) large-aperture crystal in an advanced scheme where detuning the compressor allows doubling before full compression in the 2nd harmonic in a secondary compressor. Each scheme must be deployable with ~1kJ of input energy in a beam of ~600mm diameter. Overcoming the engineering challenges of the 2-stage compression approach promises to double the power in green in a quarter of the pulse length currently being used by Orion. Comparison of simulated and experimental efficiencies across power scans for common doubling crystals show some disagreement in values and overall trends, highlighting a need for careful parameter choices, or simulations missing experimental aspects.

Dina Eissa
The Ohio State University, United States

Capturing molecular dynamics with sub-angstrom and sub-femtosecond spatial-temporal resolution is an important goal in ultrafast science. Emerging scattering techniques offer promising avenues for achieving this goal, with Laser-induced Electron Diffraction (LIED) standing out as a method to image molecules. In LIED a coherent electron wave packet is created by tunnel ionization and then the molecule is probed by its own tunneled electrons. Unlike LIED which extracts the differential cross section (DCS) from a 2-D photoelectron angular distribution, Fixed-Angle Broadband Laser-driven Electron Scattering (FABLES) connects 1-D photoelectron spectrum to atomic position with sub-picometer resolution by a simple Fourier Transform. FABLES in N_2 has previously been explored using a single color, but here we employ two colors (1700nm+850nm). The 1700 nm light performs FABLES, while the novelty in this research lies in the addition of the 850 nm light, which induces a transition from the X state to the A state of N_2^+ as the electron travels in the continuum. This transition modifies the electron density upon the electron's return, resulting in a new diffraction pattern. Changes in bond length indicate that it was possible to image nuclei movement in N_2^+ due to the X to A transition. Our results demonstrate a change when transitioning from a single color (1700 nm) to two colors (1700 nm + 850 nm). Additionally, variations in the diffraction pattern were observed with changes in the phase between the two colors. This experiment highlights the effect of extremely fast one-photon resonant transitions and reveals how electronic excitations in the ion between ionization and recollision alter FABLES. These findings open the door to new interesting studies in LIED and FABLES using a two-color scheme.

Hao Xu
Shanghai Jiao Tong University, China

Neutrons have a wide application from basic physics research to detection technology. Classical spallation pulsed neutron sources have ten nano-seconds scale time duration and restrain the application in ultrafast process detection and neutron spectroscopy. With the development of chirped pulse amplification (CPA) technology and laser wakefield acceleration (LWFA) mechanism, laser-plasma electron acceleration shows the merits of high acceleration gradient (>100s GeV/m), high beam density (>1019 cm-3), high peak current (10s kA), and most importantly, ultrashort beam duration (<100 fs). This table-top electron accelerator can drive the secondary neutron source by photonuclear reaction.In this work, We combined this ultrashort laser-driven neutron source with the single neutron counting (SNC) technology, realizing fine neutron spectrum measurement. We performed the Monte Carlo simulation to prove the neutron spectrum distribution's stability and proved the accumulation method's feasibility. We further evaluated the improved neutron energy resolution with variant flight distance and neutron time duration and showed the superiority of this ultrashort pulse neutron source.

Harijyoti Mandal
Max Planck Institute for Nuclear Physics, Germany

Extreme-ultraviolet (XUV) free-electron lasers (FELs) offer unprecedented opportunities for nonlinear multi-photon excitation and ionisation of atoms and molecules. We present a novel XUV photon spectrometer, installed at FLASH in Hamburg, capable of simultaneously measuring the fundamental (ω) and second harmonic (2ω) spectra of FEL pulses. This enables spectral tagging based on the shot-by-shot SASE structure with event-based photoionization detection in the reaction microscope[1]. This spectrometer operates at a repetition rate of 100 kHz, utilising phosphor screens and out-of-vacuum imaging onto two GOTTHARD[2] detectors. In our experiments, we used a reaction microscope to measure the three-dimensional momentum distributions of helium recoil ions by tuning FLASH near intermediate singly excited states. Building on previous observations[3] of interfering pathways between the FEL fundamental and its second harmonic, we present the variation in directional asymmetry in the photoelectron angular distribution of one-photon and two-photon ionisation in helium with an unseeded SASE FEL, influenced by the relative phase between these pathways.

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Ionut Slabu
ELI-NP, Magurele, Romania

The "Isomer production and photoexcitation" (PPEx) experiment takes advantage of the 1 PW High-Power Laser System at ELI-NP, for creating nuclear isomer levels in solid targets, through interaction with laser-produced secondary radiation like accelerated electrons or Bremsstrahlung radiation. These kind of experiments are important for the fundamental understanding of stellar conditions reactions, e.g. photon baths with temperatures ranging from 108 K (He intershell) to 2-3 109 K (deep O-Ne layers of massive stars exploding as SnelI). The main objectives for this beamtime in the E7 experimental area of ELI-NP was to achieve a stable regime of electron acceleration through LWFA in gas mixture target (98% He and 2% N) used for bremsstrahlung generation and the excitation into isomer states of Indium target.

Ionuț-Cristian Ciobanu
ELI-NP, Magurele, Romania

The primary focus of research at XIL from ELI-NP is the advancement of phase-contrast mammography and the development of a tomosynthesis system utilizing an ultrahigh sensitivity Talbot-Lau interferometer with a conventional X-ray source. In the long term, efforts are also directed toward optimizing the setup for a laser-driven X-ray source. Another key objective is improving tumor detection through the application of artificial intelligence.

The first step in this enhancement involves employing Convolutional Neural Networks (CNNs), including models such as U-Net, ResNet50, DeepLabV3, PSPNet, and SegNet, for tumor segmentation in scattering images produced by a 6-meter-long Talbot-Lau interferometer.

This poster highlights the potential of combining Talbot-Lau interferometry with CNNs to significantly improve tumor detection, presenting a promising approach for achieving more precise and efficient medical diagnostics.

Irem Nesli Erez
University of Rochester, United States

Achieving strong magnetization with the convergence of subcritical density plasma flows

Magnetized warm dense matter samples are unexplored experimentally due to the large magnetic field strengths required. The existing HED flux compression setups can reach kT strength fields with convergence of high-density plasmas. However, magnetized WDM experiments would require a clear line of sight for creation and diagnosis of the sample. Our design proposes an alternative approach for field compression with low-density and high-temperature plasmas to make magnetized WDM experiments possible. Our simulations in PERSEUS indicate that achieving such strong fields with the convergence of subcritical plasma flows is possible.

This material is based upon work supported by the Department of Energy [National Nuclear Security Administration] University of Rochester "National Inertial Confinement Fusion Program" under Award Number(s) DE-NA0004144, the Horton Fellowship, and NSF Grant Number PHY-2020249.

Jakub Kutscherauer
Gymnázium J. S. Machara, Czech Republic

When measuring BioSAXS, it is advantageous to simultaneously observe ultraviolet and visible absorption in situ, which allows detection of aggregation and radiation damage to the sample. However, when the capillary is fully irradiated, it is unfeasible to reliably use the Lambert-Beer law to convert transmission and absorbance since the optical path is not the same at all points of the capillary irradiation.

This research demonstrates and explains the significant influence of this fact on the measurement. Subsequently, a formula for the dependence of transmission and absorbance in capillary measurements is derived and experimentally verified, enabling accurate measurement of a sample's absorbance. Furthermore, the designed apparatus' limits and optimal parameters are determined to achieve the best possible results.

Jasmin Hills
Imperial College London, United Kingdom

Reflections from a plasma mirror, with an eye to staging.

Jiajun Li
Institute of Physics, Chinese Academy of Sciences, China

Here a mechanism for self-compression of laser pulses is presented, based on period density-modulated plasma. In this setup, two pump beams intersect at a small angle within the plasma, which is facilitated by the ponderomotive ion mechanism and causes a modulation in the plasma with long wavelengths and low amplitude. This modulation enhances the backward Raman scattering of the probe pulse. The probe's trailing edge experiences greater energy loss, resulting in a steeper intensity gradient and inducing an asymmetric self-phase modulation. Notably, the laser in plasma exhibits opposite group velocity dispersion compared to traditional solid-state media. This unique property allows laser pulses to undergo dispersion compensation while broadening the spectrum, ultimately leading to self-compression. In the 2D-PIC simulations, the intricate interplay among self-phase modulation, group velocity, and backward Raman scattering results in the self-compressing of the laser pulse below 1/4 critical density, without the transverse self-focusing effects.

Kalyani Chordiya
Institute for Theoretical Physics and Centre for Free-Electron Laser Science, University of Hamburg, Germany

Controlling the ring currents in organic molecules

Recent experimental and theoretical advancements in attosecond science have enabled us to revisit and verify the chemical properties of materials with unprecedented precision. In this study, we employ advanced quantum chemistry calculations to investigate ring currents in organic molecules 1,2. Utilizing the XUV pump-XUV probe technique, we initiate and observe these dynamics, generating time-resolved Photoelectron Momentum Maps (PMMs). These PMMs allow us to identify the direction of ring currents in selected organic molecules. Furthermore, we demonstrate how altering the chemical structure of these systems can control the direction of these currents.

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Krisztina Trényi-Sárosi
ELI ALPS Facility, The Extreme Light Infrastructure ERIC, Szeged, Hungary

Temperature dependent carrier dynamics of gallium alloyed CdSe/ZnS QD samples

We present the first study on the temperature dependent (between 30 °C and 130 °C) carrier dynamics of gallium alloyed CdSe/ZnS QD samples and reveal the effect of the Ga-content and temperature on the trion-decay kinetics of these systems.We demonstrate the temperature controlled TA setup of ELI ALPS Institute is suitable to observe carrier redistribution processes from a variety of relaxation pathways. We revealed that varying the temperature between 30 °C and 130 °C had negligible effect on the determined time constants of the processes, however it significantly affected the fraction of charge carriers participating in the different recombination channels. We have shown that the amount of Ga had a significant effect on the determined lifetime. We found, that the incorporated Ga promotes the formation of trions (Coulomb-blockade) in the samples, which prolongs the hot-carrier lifetime.

Lucas Ribotte
CEA, CELIA, France

Neutron sources with fluxes exceeding 10^20 - 10^21 n/cm²/s would be particularly interesting tools for the production of neutron-rich nuclei in the context of nuclear physics and astrophysics. Yet currently available sources fail to provide high-enough neutron fluxes. Short and ultra-high intensity lasers are expected to be potent drivers of bright neutron sources, especially when it comes to the upcoming multi-petawatt facilities.

This work focuses on the production and experimental characterization of a neutron source on the LMJ-PETAL facility with a total of 9 shots performed between 2023 and 2024 in the picosecond-kiloJoules pulse regime (with pulse powers between 0.37 PW and 0.96 PW). The source relies on the conversion of a Target Normal Sheath Accelerated (TNSA) proton beam into neutrons through (p,n) reaction in a pitcher-catcher configuration. Both TNSA proton and emitted neutron populations are studied through multiple experimental techniques, and the number of neutrons emitted is shown to be as high as 5x10^10 .

Maria Mincheva
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Any focused light beam experiences an axial phase shift when passing through its focus, known as the Gouy phase shift. Initially studied by Gouy, this phase anomaly is significant in microwave optics, lasers, nonlinear optics, terahertz radiation, and singular optics. The Gouy phase for a Gaussian beam is given by ΦG = atan(z/LD), where LD is the Rayleigh diffraction length and z is the longitudinal coordinate. For higher-order Hermite-Gaussian (HG) beams, the Gouy phase is scaled by the sum of the mode indices plus one (1+l+m). Despite its theoretical importance, experimental verification has been limited. In this poster, we present experimental results using a single-lens interferometer and spatial light modulator-generated higher-order HG modes. Our findings show that the retrieved Gouy phase ΦG aligns closely with theoretical predictions, validating this key concept in optics.

Maria-Gabriela Zheleva
Paisii Hilendarski University of Plovdiv, Bulgaria

Recently, new physical mechanism for trapping of neutral atoms, molecules and particles into the envelopes of femtosecond laser pulses was suggested. This mechanism is based on attractive longitudinal optical force, allowing the light atoms, such as hydrogen and helium, to be confinement into the pulse envelope and to be accelerated up to the group velocity of the pulse. The obtained results are in approximation to the first order of dispersion (group velocity) and at distances considerably smaller than the diffraction length. At these distances the longitudinal spatial shape, as well as the spot of the laser pulse, does not change and the calculations are significantly simplified.

In the current work, the dynamical properties of the attractive longitudinal optical force and the applied potential, due to diffraction and dispersion of ultrashort laser pulses at distances of few diffraction and dispersion lengths, are presented. The results are based on analytical solutions of the linear 3D+1 paraxial spatio-temporal equation with application to the longitudinal optical force.

The present developments may contribute to the creation of neutral particle laser accelerators with potential applications in medicine and energy.

Marjan Monshi
Kaunas University of Technology, Lithuania

The combined properties of graphite and metal in particle-encapsulated carbon shells offer significant potential for diverse applications, including surface-enhanced Raman scattering (SERS) for molecular investigation and bio-detection. The graphite shell provides crucial protection for nanoparticles against environmental damage, such as oxidation and strong acids. The surface properties of carbon shells are more critical than those of the encapsulated nanoparticles, directly influencing target applications. The ID/IG ratio in the Raman spectrum of graphene-based materials is the dominant method for assessing defect density. However, at high defect density regime, ID/IG decreases due to the increase of amorphous carbon into structure.

Considering such limitation, our study suggest a comparative analysis of shell encapsulation structures, using both Raman scattering spectroscopy and Transient Absorption Spectroscopy. We employ PCA analysis to classify multi-spectroscopic parameters, identifying those correlated with the first two principal components and enabling the interchangeable use of spectroscopy techniques.

Mateusz Majczak
Faculty of Physics, University of Warsaw, Poland

Scattering matrix approach to dynamical Sauter-Schwinger process

We present a newly developed method of describing the dynamical Sauter-Schwinger process using the scattering matrix approach and reduction formulas. The method is based on solving the Dirac equation with Feynman or anti-Feynman boundary conditions, which leads to the spin-resolved (helicity-resolved) probability amplitudes of created electrons or positrons. With this approach, after summing up over spin (helicity) configurations, we are able to reproduce the momentum distributions of produced particles calculated with other methods available in literature, such as with the Dirac-Heisenberg-Wigner approach. Our method, however, provides access to information about the phase of the probability amplitude, which allows us to investigate vortex structures in momentum distributions of created particles. In addition, we preserve the information about the spin (helicity) of created particles, which is not possible with other approaches.

Maya Zhekova
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Changing fs pulse parameters using prism compressor

Ultrashort (femtosecond and recently attosecond) pulses are one of the hardest to analyze in terms of pulse duration and shape since the response times of standard measuring devices are too slow. For the last decades with the increased interest in this field a number of techniques have been developed like FROG/GRENOULLE, SPIDER and interferometric autocorrelation (IA).

Dispersion gain is usually compensated with dispersion element – set of two prisms with a reflective element (mostly used inside the resonator) or chirped mirrors (both in and out of the resonator). In both cases these element compensate the natural dispersion of the pulse. Measurement of femtosecond pulse using these three techniques was conducted, altering compressor properties (prism penetration) which changes the pulse duration, group velocity dispersion, group delay dispersion, third order dispersion, a slight shift in central wavelength and bandwidth. Comparing the results with the theoretical model [1,2] we were able to confirm the behavior of the listed parameters.

Using 16 chirped reflections from 8 chirped mirrors between the oscillator and the analyzing elements we were able to compare the elongation of the pulse [3] with and without them and additionally measure GDD (given by specifications) and TOD, which was not given by the manufacturer and successfully measured.

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Acknowledgements
This work was supported by projects 80-10-17/8.4.2024г. и КП-06-Н78/6-05.12.2023г.

Maziar Moussavi
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This study presents the development and application of a novel Surface-Enhanced Raman Spectroscopy (SERS) substrate for detecting lithium-ion battery electrolyte vapors. By arranging silver nanoparticles in a periodic array, we leveraged Surface Lattice Resonance (SLR) to drastically narrow plasmon resonance linewidths, enhancing the Raman signal. A monolayer of graphene was added to the substrate to protect the nanoparticles and improve analyte adsorption. The combination of SLR and graphene led to the clear identification of multiple characteristic peaks related to electrolyte components such as ethylene carbonate (EC) and ethyl methyl carbonate (EMC). This enhanced sensitivity allows for early detection of electrolyte leaks, crucial for preventing battery failures. Our capillary-assisted particle assembly method proved reliable and straightforward for creating the periodic nanoparticle array. These findings highlight the potential of SLR-enhanced SERS substrates in improving battery safety and performance through advanced chemical sensing.

Mihail Miceski
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The LINAC-based Free Electron Lasers, which is known as the fourth generation of synchrotron radiation sources, provide an intense source of brilliant X-ray beams for the worldwide user community to investigate matter at the atomic scale with unprecedented time resolution. In the frame of this presentation, we explore the development of a novel compact Laser-Plasma Accelerator (LPA) based Free Electron Laser (FEL) operating in the extreme ultraviolet (EUV) range of the radiation spectrum. However, achieving the desired electron beam parameters within a single-unit Swiss-FEL type undulator (as a commercially available option) presents a significant challenge.

The presentation will cover the design of an optimal electron-beam transport line for the LPA-based FEL, highlighting the essential requirements of the LPA-based electron beam parameters. It will explore two options, EQMs and APL, for capturing electron beams from a compact laser-plasma accelerator to reach the saturation of the FEL power. Special attention will be given to minimizing the dilution of the normalized transverse RMS emittance, which is a critical parameter for high-quality FEL radiation. Additionally, to achieve the required slice energy spread and slice peak current, the implementation and design analysis of the CHIC magnet will be discussed. By addressing these challenges, this research aims to pave the way for a compact and powerful EUV light source utilizing laser-plasma accelerator technology.

Mohammad Esmaeil Daraei
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Terahertz photoconductive antennas simulation: a finite element approach

The Terahertz (THz) band, located between the microwave (MW) and infrared (IR) regions of the electromagnetic (EM) spectrum, has garnered significant research interest [1]. THz radiation has potential applications in various fields, including wireless communication, explosive detection, pharmaceuticals, spectroscopy, and imaging [2].

This study employs the finite element method to simulate the THz photoconductive antenna (PCA) by solving Maxwell's wave equations alongside the coupled drift-diffusion and Poisson's equations. The computational modelling is divided into two steps: (1) calculating the optical response by determining the spatial distribution of the optical field and (2) determining the electronic response by solving the time-domain forms of the coupled drift-diffusion and Poisson's equations, using carrier generation derived from the first step.

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Improved light harvesting with graphene/boron nitride nano-heteroislands: a high-efficiency photosensitizer design

In the present study, investigates the structural, electronic, and optical properties of hexagonal boron nitride (h-BN), graphene/boron nitride (G/h-BN), and defected graphene/boron nitride (R-G/h-BN) nanostructures using density functional theory and time-dependent density functional theory. A carbon atom was removed from G/h-BN, introducing a Stone-Walls defect. Critical parameters for solar cell sensitizers, including electron injection free energy (〖ΔG〗_Inj), regeneration energy (〖ΔG〗_Reg.), light harvesting efficiency (LHE), and open circuit voltage (V_OC), were assessed. The results demonstrate that all nanostructures effectively inject electrons into the conduction band of TiO2, with G/h-BN exhibiting a stronger light response and a red shift in the UV-Vis spectrum at 372.95 nm. Additionally, G/h-BN and h-BN nanoislands show superior stability compared to traditional dyes like ruthenium and platinum complexes. These findings suggest that G/h-BN and h-BN are promising candidates for use in solar cell sensitizers, offering both efficiency and stability.

Mojtaba Shirozhan
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Spatio-spectral optimization of the focal spot for relativistic high harmonic generation

The efficient generation of high harmonics and XUV beam from surface plasma (plasma mirror) is highly dependent on the interaction parameters, including peak intensity of the drive pulse, electron density of the plasma and the geometry of the interaction, etc [1,2]. Here, the objective of this study is to optimize spatio-temporally the focal spot of the laser beam delivered to SHHG-SYLOS beamline at ELI ALPS. First, by presenting the PIC simulation results the significance of the peak intensity of the pulse, interacting with the plasma target is highlighted [3]. Then, we report the processes, which are followed to optimize the spatial extent and temporal duration of the focal spot. Finally, the obtained focal spot is characterized by qualifying its spectrally-resolved spatial profile. This factor, in general, reveals the existence of any aberrations in the focal spot.

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Owen Lawrence
University of York, United Kingdom

This poster presents an overview of x-ray generation methods via Laser Wakefield Acceleration (LWFA), a technique that utilises high-intensity laser pulses to accelerate electrons to relativistic speeds within a plasma. The core mechanism of LWFA is explored, emphasising the role of the normalised vector potential (a0) in defining different plasma regimes, from linear to nonlinear. Various electron injection methods and x-ray generation methods from the accelerated electrons are discussed.

Patrick Dalton
University of Manchester, United Kingdom

Laser-driven terahertz (THz) sources offer a path to compact, high-gradient acceleration versus radio-frequency technology, providing femtosecond control, compression, synchronisation, and diagnostics for electron beams. However, low availability of narrowband, high-energy THz sources has created an obstacle in the field. Stacking sub-mm thickness lithium niobate wafers, with each new wafer rotated by 180 degrees, is a recent idea to mimic the domain structure of the narrow bandwidth Periodically-Poled Lithium Niobate (PPLN) scheme, with the additional advantage of large surface area. Recently, we have demonstrated that cryogenic cooling of these wafer stacks to <100 K can reduce THz losses through the stack. This allows for an increase in the number of stacked wafers, providing higher-energy and narrower-bandwidth THz. We produced 24 cycle THz pulses at 0.39 THz with a total pulse energy of 0.55 mJ, paving the way for the adoption of THz as a new tool for accelerator science.

Pritha Dey
Max Born Institute, Germany

High energy few-cycle mid-IR sources are effective in providing table-top high cut-off energy high harmonic generation (HHG). Soft X-rays in the few hundreds to keV range could be produced by these sources which are an important tool for studying electron dynamics in the condensed phase systems such as functional materials based on metal constituents. An efficient way to generate such powerful mid-IR pulses is to combine high-power solid-state lasers with optical parametric chirped pulse amplification (OPCPA). Here, we present a 10 kHz repetition rate OPCPA system at 3.1 µm central wavelength. The mid-IR system generates pulses of 11 W average power at a temporal width of 58 fs. We are on the path to improve the output upto 15W with improved optical elements and pulse-front corrections. These short pulses provide the path to generate high-cutoff HHG and to access L-absorption edges in metals for studying electron dynamics in functional materials.

Sajjad Vardast
Umeå University, Sweden

The realization of attosecond-time-resolved XUV pump

XUV probe experiments is one of the big challenges of attosecond physics. Over the last decade, a few groups used this technique to measure electron dynamics in various interactions. However, those experiments were limited to photon energies below 50 eV. Here, we present a new intense source of XUV attosecond pulses with up to ~140 eV.

Sara Aleksandra Lukasik
University of Warsaw, Poland

The poster presents the construction of a radiometric goniometer designed for measuring the wavefront of mid-infrared lasers in spherical coordinates. The design is based on two rotating stages and an infrared detector. The device allows comprehensive scanning across an entire hemisphere with a customizable radius. To enhance measurement accuracy, the laser light is additionally modulated with current.

Tanner Nutting
University of Michigan, United States

We present a new acceleration scheme capable of accelerating electrons and ions in an underdense plasma. Transversely Pumped Acceleration (TPA) uses multiple arrays of counter-propagating laser beamlets that focus onto a central acceleration axis. Tuning the injection timing and the spacing between the adjacent beamlets allows for precise control over the position and velocity of the intersection point of the counter-propagating beam arrays, resulting in an accelerating structure that propagates orthogonal to the direction of laser propagation. We present the theory that sets the injection timing of the incoming pulses to accelerate electrons and ions with a tunable phase velocity plasma wave. Simulation results are presented which demonstrate 1.2 GeV proton beams accelerated in 3.6 mm of plasma and electron acceleration gradients of 2.5 TeV/m in a scheme that circumvents dephasing. This work has potential applications in medical physics, proton radiography, and high energy physics colliders.

Tatiana Aureliia Uaman Svetikova
Helmholtz-Zentrum Dresden-Rossendorf, Germany

Efficient THz upconversion with dirac materials

Current communication technologies are constrained to sub-THz bands due to the frequency limits of traditional nonlinear components. We introduce a new approach to upconverting weak sub-THz signals into multiple THz bands using a high-mobility HgTe-based heterostructure with Dirac electronic state dispersion. Building on our previous success in achieving record third harmonic generation in this material, we anticipated efficient frequency mixing and a strong THz response across various input frequency combinations. With a field conversion efficiency exceeding 2% in a sub-100 nm HgTe layer at room temperature, we hope to open the door to highly integrated THz communication devices with very high data transfer rates.

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The project FLAMAT – femtosecond laser modification of different materials

Femtosecond laser modification induces permanent changes in material surfaces on micro- and nano-scales, altering topography, crystal structure, chemical composition, and polymerization to enhance functionality. This project investigates the effects of femtosecond laser modification on the physico-chemical properties and functionality of optical components for laser and optics industries. The focus is on optical coatings (e.g., ZrO2, TiO2, Al2O3, SiO2) and substrates for thin film deposition. In-depth studies will explore the mechanisms and effects of laser-induced modifications on optical linear and nonlinear properties, chemical structure, morphology, and surface topography. The influence of key laser processing parameters like wavelength, pulse duration, repetition rate, and laser fluence will be examined.

Acknowledgements
This research was funded by the Bulgarian National Science Fund under the National Scientific Program “Petar Beron i NIE”, contract No. KP-06-DB/9.