44th International Workshop on High-Energy-Density Physics with Intense Ion and Laser Beams

January 28th – February 3rd, 2024

Darmstädter Haus (Waldemar Petersen Haus)

Hirschegg, Austria

P r o g r a m

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Status of the FAIR Project

Peter Spiller[1]

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The FAIR project is progressing well. Most of the civil constructions works have been completed. Major technical infastructur for the FAIR accelerator complex has been delivered and installed. The central cryo plant, with the large cold box from Linde and the room temperature compressor stages have been installed in the dedicated buiding. The set-up of the cryogenic distribution system has been completed in the SIS100 tunnel. As most important milestone, the so-calles string test, which consists of one lattice cell of the SIS100 arc has been completed and a first thermal cycle has been completed successfully. After completing the technical building infrastracture installations in the Western part of the SIS100 tunnel, accelerator installation has been lauchend in January 2024. In order to strenghen the effort for an early science with the Super-FRS, a decited task force has be established. Further major components haven been contracted, as the large CBM detector magnet or items replacing the former Russian inkind contributions such as HEBT beam guiding magnets and vacuum chambers.

Status of HIAF

WenLong Zhan[1]

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tba

Updates on the HED@FAIR Collaboration

Kurt Schoenberg[1]

[1]HED@FAIR COLLABORATION

The Facility for Antiproton and Ion Research in Darmstadt is now well advanced in its construction. The civil construction has delivered its first buildings in which the installation of the first accelerator components should commence in a few weeks, at the beginning of 2024.
Over the past several years, multiple financial issues, driven by project-related and international events, have driven significant changes to FAIR and GSI-based research plans. Project-based cost increases and consequences due to the Ukraine conflict involving sanctions against Russia have driven FAIR to re-baseline its construction and turn-on schedule. The FAIR Council has emphasized that completion of the MSV remains its strategic goal and that experimental beamtime at the existing GSI facilities, until the start of the corresponding FAIR science programs, is essential for all FAIR

collaborations. Nevertheless, there remain significant consequences for our HED@FAIR collaboration. This talk will give an overview over the FAIR project status and it will also summarize the HED@FAIR Collaboration plans to maintain a competitive research program through the transition to FAIR MSV project completion.

Efficient, High Peak-Power, Short Pulse Lasers for Fusion Applications

Georg Korn[1], *Erhard Gaul*[1], *Hartmut Ruhl*[2]

[1]Marvel Fusion
[2]Marvel Fusion GmbH

We will discuss the principal physical concepts and technologies for developing high efficiency PW lasers. Using directly diode-pumped broadband laser materials and state of the art optics and photonics technologies a new generation of compact high contrast PW lasers with high wall plug efficiencies and increased repetition rates (10 Hz) in the sub-100fs can now be envisioned and build as a versatile laser platform. Combining multiple beams opens a path to multi-PW and Exawatt peak-power generation for different applications including the new fusion concept based on efficient laser to ion conversion in nanostructured materials [1, 2, 3]. We will present the parameters of the laser platform and how to achieve high wall-plug-efficiencies (WPE).
The petawatt laser is based on optical parametric chirped pulse amplification (OPCPA) and subsequent broadband amplification followed by grating compression [4]. High (WPE) is possible by use of diode pumping, efficient energy extraction in the broadband power amplifier, and minimizing losses during compression. Multilayer dielectric gratings with large aperture, sufficient bandwidth, and good laser induced damage threshold have been demonstrated [5], which enable compression with 90-95% efficiency, and an overall WPE above 10%. Marvel Fusion has successfully performed contrast-improving measures at several petawatt facilities such as second harmonic generation (SHG) of petawatt pulses [6] to evaluate its feasibility for laser systems.

Furthermore, direct-drive fusion compression experiments will benefit as well from shaped pulse nanosecond pulses with increased bandwidth followed by SHG which can be generated with the same laser amplifier technology. This will allow better control of plasma instabilities due to a decreased coherence length of laser beams. The proposed laser platform is currently under development and will have widespread use in different laser fusion schemes which are currently investigated.

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Present and Future HED Facilities at First Light Fusion

Nicholas Hawker

First Light Fusion (FLF) is developing a new method for inertial fusion that uses one-sided drive. The key aspect of the technology is a component called the ”amplifier”. The amplifier couples energy from the driver, with a high-velocity projectile being FLFs preferred approach, to a final fuel capsule. The amplifier performs two functions. First, it creates a planar to spherical focusing, such that the final fuel capsule implosion is spherical, as with other approaches to inertial fusion, despite the one-sided drive. Second, it enhances the pressure delivered to the fuel capsule beyond the initial drive pressure. The design of FLFs new pulsed power facility, M4, will be reported. The objective of this facility is to reach ignition with the one-sided drive approach. And in addition, a planar-to-planar amplifier design, called the Endor amplifier, will be presented in detail. This offers HED researchers a new ability to reach high-pressure states of matter on much simpler, lower cost facilitates, for example reaching more than 10 MBar shock pressures in quartz on a two-stage gas-gun facility like FLFs BFG.

Applications and User Demands of Next Generation High Energy, High Repetition Rate Lasers

Zsuzsanna Slattery-Major[1], Vincent Bagnoud[1]

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Within the EU-funded THRILL project (Technology for High-Repetition-Rate Intense Laser Laboratories) several institutions are forming a consortium to develop technologies that allow the operation of high-energy lasers at increased repetition rates. The overall goal of the project is to identify the most appropriate architecture of the next generation high-energy-laser systems to be used in combination with the large-scale European research facilities Eu-XFEL and FAIR. In addition to the technological advances, the applicability by the respective users to their fields of research is crucial. A survey, which took the form of a workshop, has allowed us to obtain an overview of the current state-of-the-art applications of high-energy lasers and on the desired development directions from the users' side.

After a brief introduction to the THRILL project, we will present the main findings of the workshop discussions. These reveal that kJ-class, long pulse (ns) lasers at a repetition rate of 1 shot/few minutes would allow to access a wide range of new physics questions and represent a “game changing” development for many research fields, including warm-dense matter research, dynamic compression, high-field QED, nuclear photonics, inertial fusion energy, magnetic field generation, and laboratory astrophysics. In addition to the laser parameters, diagnostics and target handling are limiting factors in many cases, which need to be further developed in parallel. Bringing together the community, also highlighted many points of connection and synergy opportunities.

High-Power Low-Coherence Laser Driver Facility

Xiaohui Zhao[1]

[1]Shanghai Institute of Laser Plasma

Laser-plasma instability (LPI) is one of the most challenging issues, and the possibility of low-coherence drivers (broad bandwidth and low phase correlation) has been extensively discussed in the fields of laser plasma physics and laser technology. High-power low-coherence laser has attracted widespread interest. Here, we demonstrate the results for high-power low-coherence laser named KUNWU which delivering 1-kJ, adjustable ns-level pulses with a coherent time of 249 fs and a bandwidth of 13 nm. The fluence is up to 5 J/cm2 corresponding to a intensity of 1.7 GW/cm2. The pulse waveform and spectral distribution can be independently and precisely adjusted, showing an instantaneous broadband characteristics. Utilizing a large-aperture partially deuterated KDP crystal as the nonlinear medium, the second-harmonic generation (SHG) efficiency of low-coherence pulse can be up to 63%. The low-coherence smoothing method, which combining a continuous phase plate (CPP) with the induced spatial incoherence (ISI) is demonstrated, and a 14.7% rms nonuniformity of the focal spot is achieved. This facility successfully demonstrates the generation, amplification, transmission, nonlinear conversion and system integration technologies of the broadband low-coherence laser driver. It has great potential in the field of ICF and high-energy density physics research.

Advancement of High Intensity Laser Driven Particle Accelerators to Application Readiness

Ulrich Schramm[1]

[1]HZDR

Improved control of high intensity laser beam parameters on target recently enabled proton energies beyond 100 MeV, dose-controlled sample irradiation experiments, and the demonstration of seeded FEL light.
This presentation focuses on the chain of developments at the Petawatt laser DRACO at Helmholtz-Center Dresden-Rossendorf that enabled the first dose controlled systematic irradiation of tumors in mice [1] with laser accelerated protons. Details on acceleration mechanisms and strategies to increase stability and energy will be discussed [2] as well as beam transport by means of a dedicated pulsed solenoid beamline to a secondary target together with online metrology and dosimetry. In parallel, improved control of interaction parameters together with different types of targets operated close to relativistic induced transparency enabled the exploitation of acceleration mechanisms surpassing target normal sheath acceleration [3,4]. Here proton energies well beyond 100 MeV could be reached

at repetition rate compatible laser parameters.
With improved LWFA parameters, in particular spectral charge density and beam divergence, a dedicated beamline operated by Synchrotron Soleil at HZDR enabled the first observation of seeded FEL light from a laser plasma electron accelerator. Strategies to develop this source to the EUV range, of interest for probing of plasma densities relevant for ion acceleration, will be discussed.

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Peaks and Valleys Asymmetry in the Linear Rayleigh-Taylor Instability on Elastic-Plastic Solids

Antonio Roberto Piriz[1], Sofía Ayelen Piriz[2], Naeem Ahmad Tahir[3]

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Rayleigh-Taylor instability is a key issue in many experiments on high-energy density physics (HEDP) and in inertial confinement fusion. Some implosion driven experiments like LAPLAS (Laboratory Planetary Science), being designed in the framework of the international collaboration on HEDP developed around the heavy ions accelerator FAIR (Facility for Ion and Antiproton Research, presently under construction at the GSI Darmstad (Germany), relay on the mechanical properties of the pusher for the control of the hydrodynamic instabilities. The generation of spikes and bubbles, a typical characteristic of the non linear regime in the Rayleigh-Taylor instability, is found to occur as well during the linear regime in an elastic-plastic solid medium caused, however, by a very different mechanism. This singular feature originates in the differential loads at different locations of the interface, which makes that the transition from the elastic to the plastic regime takes place at different times, thus producing an asymmetric growth of peaks and valleys that rapidly evolves in exponentially growing spikes, while bubbles can also grow exponentially at a lower rate.

The Liquid Structure of Carbon Elucidated by in Situ Probing at EuXFEL

Dominik Kraus[1], Collaboration of the EuXFEL Community Proposal #2740

[1]HZDR

Carbon plays a central role in biology and organic chemistry and its solid allotropes provide the basis of much of our modern technology. As such, carbon is nowadays one of the most studied chemical elements. However, the liquid form of carbon, which does not exist at ambient pressure, remains elusive due the challenging experiments required for characterizing this state. Indeed, the structure of liquid carbon and most of its physical properties are essentially unknown. At the same time, liquid carbon at Mbar pressures is highly relevant for modeling planetary interiors, dynamic processes where carbon-containing materials are rapidly heated such as inertial confinement fusion or hypervelocity impact events, and our general understanding of fluids at extreme conditions. Here we present a precise structure measurement of liquid carbon at pressures around one million times ambient obtained by in situ X-ray diffraction obtained at EuXFEL from carbon samples that were shock-compressed using the new DiPOLE 100X drive laser. Our results show a complex fluid with short-time tetrahedral bonding in agreement with quantum molecular dynamics simulations. This substantiates our understanding of the liquid state of one of the most abundant elements in the universe and opens the path to perform similar studies of the structure of liquids composed of light elements at extreme conditions.

Laser-Driven X-Ray Diagnostics of Heavy-Ion Heated Matter at the HHT Station of GSI

Philipp Hesselbach[1], Julian Lütgert[2], Vincent Bagnoud[3], Roman Belikov[4], Carlos Butler[5], Oliver Humphries[6], Björn Lindqvist[7], Alice Renaux[8], Gabriel Schaumann[9], Andreas Tauschwitz[3], Dmitry Varentsov[3], Karin Weyrich[3], Bjoern Winkler[10], Xiao Yu[3], Bernhard Zielbauer[3], Dominik Kraus[11], David Riley[12], Zsuzsanna Slattery-Major[3], Paul Neumayer[3]

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[11]HZDR
[12]QUB

The HHT target station at GSI offers the unique possibility of combining intense bunches of high-energy heavy-ions from the SIS-18 heavy-ion synchrotron with high-energy laser pulses delivered by the PHELIX laser. Bunches of up to 4×10^9 heavy-ions (e.g. U^{73+}) within 400 ns can be focused in a < 1 mm^2 spot onto a sample which is then volumetrically heated to several thousand Kelvins. Time-resolved diagnostics of structural changes and the heating dynamics is enabled by laser-driven X-ray sources.

In first experiments, we probed heated states of diamond and iron by X-ray diffraction and X-ray Thomson scattering. We have now extended our diagnostic capabilities by X-ray absorption spectroscopy for aluminum. Detecting absorption spectra of cold aluminum, we have optimized the laser-driven X-ray source and spectrometer setup. In contrast to the typical use of rare-earth elements as backlighter target, we have found Teflon to be more beneficial because of its flat emission spectrum.

We will introduce the experimental setup of heavy-ion heating combined with laser-driven X-ray diagnostics, present our findings concerning the backlighter optimization for absorption spectroscopy of aluminum and give an outlook for the upcoming combined experimental campaign in 2024.

Low-Entropy Compression of Matter Using Intense Heavy Ion Beams at FAIR: Application to Planetary Physics

Naeem Ahmad Tahir[1], *V. Bagnoud*[2], *Paul Neumayer*[2], *A.R Piriz*[3], *S.A Piriz*[3]

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Hydrodynamic simulations have shown that intense ion beams are a very effective tool to produce large samples of High Energy Density (HED) matter using dynamic implosion that leads to a low-entropy compression. Such a scheme, named, LAPLAS (Laboratory Planetary Science), generates physical conditions that are expected to exist in the cores of different planets. Recently, we have carried out extensive simulations of carbon compression that shows that the carbon sample can be compressed to 2 - 3 times solid density, pressures of 5 - 10 Mbar can be achieved, whereas the temperature remains between 2000 - 8000 K. This information can be useful in studying the properties of carbon rich planets. Moreover, one may discover new carbon phases as well as one can research the special type of diamond named diaphites which have been found at asteroid impact sites.

Ab Initio Calculations of Conductivities Under Planetary Interior Conditions

Martin Preising[1], *Martin French*[1], *Maximilian Schörner*[2], *Mandy Bethkenhagen*[3], *Argha Roy*[1], *Uwe Kleinschmidt*[1], *Ronald Redmer*[2]

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[3]École Polytechnique, Palaiseau, France

We summarize our recent efforts to calculate thermal and electrical conductivities under planetary interior conditions with ab initio simulations. We employ density functional theory coupled with classical molecular dynamics, followed by linear-response calculations within the Kubo-Greenwood formalism to compute the dynamic electrical conductivity. This quantity then gives us access to the DC electrical conductivity, the thermal conductivity, and other quantities.

![Figure 1 : DC conductivity along planetary P-T paths for Jupiter (orange) [2] and Saturn [3] (black)][1]

We applied our method to state-of-the-art models [1] for the gas giant planets Jupiter [2] and Saturn [3]. We found a profound impact of the proposed helium-rich layer above Saturn's core on thermal and DC conductivity profiles (see Fig. 1). The results will affect future magnetohydrodynamic simulations for Saturn's magnetic field.
The ice giant planets Uranus and Neptune are not too well constrained by observa-tional data. We find that the linear mixing approximation for mixtures of hydrogen and methane results in deviations of less than 4% compared to simulations of the full mixture. Our results show a steady increase in DC conductivity along Uranus' P-T path [4].
A recent study of fcc and hcp iron over a P-T range covering Earth's core-mantle boundary and inner core boundary resulted in fit formulas for the DC and thermal conductivity [5], applicable to all rocky planets with an iron core.

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[5] Kleinschmidt et al., Phys. Rev. B, 107, 085145 (2023).

The Dawn of Inertial Fusion Energy Research

Siegfried Glenzer[1]

[1]SLAC National Laboratory/RISE Fusion Energy Hub

With the demonstration of fusion ignition and steady progress towards high-gain inertial confinement fusion implosions on the National Ignition Facility, the U.S. Department of Energy has launched a new program in Inertial Fusion Energy (IFE) research. In late 20023, three fusion hubs have been selected to advance the field, i.e., the IFE-COLoR, Starfire and Rise collaborations. The latter will be co-led by Colorado State University and SLAC National Accelerator Laboratory and will focus on the development of laser driver technologies, scalable target manufacturing processes, and the experimental validation of IFE physics of designs of high-gain laser targets. In addition, the RISE hub has a strong focus on workforce development and education. In this presentation, I will touch on these activities and describe recent research highlights where we use the world's brightest x-ray free electron laser sources to probe the physical properties of extreme matter states on ultrafast time scales. Experiments have revealed the formation of diamonds from hydrocarbons at high pressures1-4. By resolving the formation kinetics, we find that de-mixing time scales are pressure dependent thus resolving the differences in pressures ranges found in dynamic compression experiments compared to those found in diamond anvil cell studies. These findings on the miscibility of species are important for the physics of laser-driven fusion fuel in IFE targets where polymer foams are a preferred way of delivery.

References:
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2. S. Frydrych et al., Nature Comm. (2020); X-ray Thomson scattering
3. Z. He et al., Science Advances, (2022); Small Angle X-ray Scattering
4. M. Frost et al., Nature Astronomy (2024); X-ray heated DAC

Tuesday (January 30st)

Start	Duration	Speaker	Title
Session 4: Proton-Boron Fusion and Other Approaches (Chair: J. Honrubia)			
08:30	0:20	ZHOU, Weimin	Production and Application of High-energy Particles Based on High-intensity Lasers
08:50	0:20	MURAKAMI, Masakatsu	Proton-Boron (pB11) Fusion as an Application of Microbubble Implosions
09:10	0:20	LIU, Bing	Recent Progress in ENN's Proton-Boron Fusion Research
09:30	0:20	ZHENG, Chuan	New Developments for Polarized Fusion
09:50	0:20	MATEO, Alfonso	Two-Dimensional Simulations of Proton Fast Ignition Cone-In-Shell targets
10:10	**00:30**	**Coffee break**	
Session 5: IFE Concepts (Chair: D. H. H. Hoffmann)			
10:40	0:20	RUHL, Hartmut	A Novel ICF Concept Based on Mixed Nuclear Fuels Heated with the Help of Nano-Structured Meta Materials
11:00	0:20	MEYER-TER-VEHN, Juergen	New Ideas Concerning Inertial Fusion Energy (IFE)
11:20	0:20	MOSES, Ronald	Performance Limits for Magneto Inertial Fusion Reactors
11:40	0:20	CANAUD, Benoit	Direct-Drive Inertial Confinement Fusion Studies for LMJ at CEA: Status and Prospect
12:00	0:20	SAUFI, Abd Essamade	FLAIM: a Volume Ignition Model for the Compression and Thermonuclear Burn of Spherical Fuel Capsules
12:20		**Lunch break**	
Session 6: Laser Technology and IFE (Chair: S. LePape)			
17:00	0:20	WENG, Suming	Control of Parametric Instabilities in Inertial Confinement Fusion with Low-Coherence Lasers
17:20	0:20	ZÄHTER, Sero	Investigation of Laser Plasma Instabilities Driven by 527 nm Laser Pulses Relevant for Direct Drive Inertial Confinement Fusion
17:40	0:20	HANGHANG, Ma	A Parallel GPU Code for the Simulation of Laser Plasma Instabilities in Large Scale Plasmas with Kinetic Effects
18:00	0:20	SAUFI, A. E.	FuSE: A Rapid, Full-System Tool For Projectile-Driven Inertial Confinement Fusion Design And Optimisation
18:20	0:20	WANG, Peipei	Backward Scattering of Laser Plasma Interactions from Hundreds-of-Joules Broadband Laser on Thick Target
18:40	0:20	VOLPE, Luca	The ELI-Germany Laser-Induced-Fusion Project
19:15		**Dinner**	**(only for house guests)**
20:30		**IFE Round Table**	

Production and Application of High-Energy Particles Based on High-Intensity Lasers

Weimin Zhou[1]

[1]National Key Laboratory of Plasma Physics, Laser Fusion Research Center

High-energy particles such as protons, electrons, neutrons and X-rays produced by high-intensity laser are of high flux, short pulse duration and tiny focal spot. Applications like high spatial and temporal resolution point-projection backlight radiography of such high-flux particles are important diagnostic techniques for the inertial confinement fusion and other high energy density physics. Short pulse proton beams and X-rays were generated by the picosecond petawatt laser beams on XG-III and SG-? upgrade laser facilities. The spectrum, conversion efficiency and resolution of such particle beams were characterized in the experiments. The applications such as backlight radiography were successfully applied to obtain the images of the compressed fuel of inertial confinement fusion targets, and the ejecta of shock-loaded materials.

Proton-Boron (pB11) Fusion as an Application of Microbubble Implosions

Masakatsu Murakami[1]

[1]Osaka University

Microbubble implosion is a novel concept, by which such unprecedented physical quantities as ultrahigh electric fields beyond 10^16 V/m and ultrahigh compression density beyond hundreds of thousands of times the solid density can be expected to be achieved under current laser technology. In microbubble implosions, a micron-sized solid target, which contains many sub- micron-sized bubbles, is first irradiated by ultra-intense ultra-short lasers. Energetic hot electrons are then produced to fly in the solid and embedded bubbles at a speed close to the speed of light. As a result, those hot electrons distribute rather uniformly in the whole target volume to generate spherically symmetric electric fields pointing the bubble centers. Bubble- surface ions are strongly accelerated to the center to achieve ultrahigh electric fields and ultrahigh compression of matter at the end of the implosion. We apply the microbubble implosion to fusion reactions such as pB11 as well as orthodox DT (deuterium-tritium) and/or DD (deuterium-deuterium) reactions. We address the optimization of the laser and target parameters for those fusion reactions. The detail of the simulation and analysis will be provided at the meeting.

Recent Progress in ENN's Proton-Boron Fusion Research

Bing Liu[1], *Yongtao Zhao*[2], *Dieter H.H. Hoffmann*[3], *Zhi Li*[1], *Di Luo*[1], *Huasheng Xie*[1], *Yuejiang Shi*[1], *Tiantian Sun*[1], *Xiaohua Chen*[4], *Wenjun Liu*[1], *Guanchao Zhao*[1], *RUI CHENG*[5], *Haozhe Kong*[1], *Yingying*

Li[1], Muzhi Tan[1], Y. K. Martin Peng[1], Tieshuan Fan[6], Huarong Du[7], Dong Wu[8], Jiaqi Dong[1], Minsheng Liu[1]

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ENN's fusion research is oriented towards energy commercialization. The primary strategy involves integrating p-11B fusion with a spherical torus (ST), leveraging aneutronic reactions to achieve a more compact design and higher performance. We built our first generation ST device EXL-50 in October 2018. After demonstration of solenoid-free plasma startup and current maintenance and with a record non-inductive ECRH current drive achieved, EXL-50 has now completed it upgrade to EXL-50U for higher plasma performance. ENN's p-11B fusion research is organized based on three pillars. The first is on the fundamental of p-11B reaction physics, through beam-target experiments [2] and cross-section measurements, through collaboration with accelerator/laser fusion community. The second is to explore p-11B burning physics in a toroidal magnetic confinement environment, currently focusing on the evaluation of the conditions for p-11B fusion in EHL-2, our next generation device. The third is to study the characteristics of hydrogen-boron plasma, from the perspectives of equilibrium, stability and transport [3]. Recent progress and challenges in these studies will be presented.

New Developments for Polarized Fusion

Chuan Zheng[1], Ralf Engels[2], Markus Büscher[3]

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[2]Forschungszentrum Jülich
[3]Forschungszentrum Jülich(FZJ)

Polarized fusion has long ago been proposed as a method to increase the efficiency of fusion reactors by aligning the nuclear spins [1]. However, the required nuclear spin-polarization conservation in fusion plasmas has never been proven experimentally. Here we report on first experimental data from the PHELIX laser at GSI Darmstadt suggesting an increased ion flux from a polarized ^{3}He target heated by a PW laser pulse as well as evidence for an almost complete persistence of their nuclear polarization after acceleration to MeV energies. These findings also validate the concept of using pre-polarized targets for plasma acceleration of polarized beams [2].

In the second part we will present a new method for producing the required polarized fuel in a simple and energy efficient way. The method is based on a so-called Sona-transition unit, in which beams of atoms, molecules or ions can be polarized up to *P* 90% – basically without limitation of the beam intensities – by means of a coherent and monochromatic radio-wave pulse. The technique should also work for a variety of samples; thus it opens the door for a new generation of polarised fuel for fusion reactors [3].

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[2] First evidence of nuclear polarization effects in a laser-induced 3He fusion plasma. doi: 10.48550/arXiv.2310.0
[3] A universal method to generate hyperpolarisation in beams and samples. doi: 10.48550/arXiv.2311.05976

Two-Dimensional Simulations of Proton Fast Ignition Cone-in-Shell Targets

Javier Honrubia[1], Matthias Brönner[2], Deborah Callahan[3], Pravesh Patel[3], Markus Roth[4], Alfonso Mateo[5]

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The direct drive proton fast ignition scheme [1] is a candidate for producing energy at scale. It relaxes the compression requirements, allowing for the reduction of number of beams, increase of laser energy coupling and the large-scale manufacturing of low-cost targets. For a proton beam to reach and heat the compressed fuel, the presence of a hollow cone embedded in the shell is required. At least two-dimensional simulations of the target compression and ignition are needed in order to obtain the laser and target requirements [2].

We have adapted the radiation-hydrodynamics code FLASH [3] to study the compression of such targets. This has been achieved mainly by dealing with the modelling of the equations of state, equilibrium at material interfaces and filtering numerical noise. The simulations show phenomena like Rayleigh-Taylor instabilities at the shell, Kelvin-Helmholtz from the shell-cone slip, cone ablation and the propagation of shocks at the cone walls and tip. The resulting density, temperature and velocity profile is then given to the PETRA hybrid code [4] to calculate the proton heating and thermonuclear burn, which is very sensitive to both density and proton beam properties [5].

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A Novel ICF Concept Based on Mixed Nuclear Fuels Heated With the Help of Nano-Structured Meta Materials

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Advanced mixed fuel types may offer interesting options for a novel ICF concept with improved commercial viability. They tend to retain a larger fraction of the α-particle energies in their natural uncompressed form. In addition, with the help of ions they can be heated extremely fast to fusion power levels exceeding energy loss on time scales orders of magnitude shorter than the available confinement time. In the presentation, we introduce the proposition of employing meta materials consisting of embedded ordered nano-structures interacting with short-pulse lasers for fast fuel heating. Notably, the proposed meta materials combined with arrays of ultra-short laser pulses can exhibit superior efficiency, control, energy, and power absorption capability compared to random foams, regular plasma or surface interfaces irradiated by long laser pulses. In the presentation, we assess the reactive capability of a number of advanced mixed fuel types. We discuss the energy and power absorption capabilities of nano-structures. They have the ability to efficiently and swiftly transfer large fractions of laser energy to ions. The accelerated ions are rapidly stopped by the mixed fuel types, resulting in fast fuel heating, but also contamination. In the present paper we link ordered nano-structures irradiated by ultra-short laser pulses with a simplified ICF model. We investigate the extent to which advanced mixed fuel types,including those that are contaminated by external energy carrying ions, can undergo fusion. We predict mixed fuel gains $Q_F \geq 1$ at MJ external energy levels without fuel pre-compression. We point out that the required laser technology is available and that related experiments with nano-structures are carried out. We point out that high gain designs are straight forward. We point to the open source development project and yellow press articles for reference [1,2,3,4].

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New Ideas Concerning Inertial Fusion Energy (IFE)

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New ideas concerning IFE are presently discussed controversially. One of these is to deposit the driver energy directly into non-compressed DT fuel, absorbing laser energy in nano-structured wire arrays much more efficiently than in the traditional Livermore design. It is claimed that fuel ignition can be reached with MJ pulses, similar to the recent results at NIF, but with a radically different target design [1]. Energy deposition has to occur on a subpicosecond timescale, such that the wire structure still exists. Notice that this timescale is shorter than the one on which thermalization occurs and fusion processes develop. Another very important point is that Z>2 material in the fuel is
required, not forbidden. Of course, this increases bremsstrahlung losses, but it also increases stopping powers of charged particles in the fuel, in particular that of fusion α-particles. It is found that this can compensate for the drawbacks due to bremsstrahlung and low fuel density. It is my impression that this basic point has not been appreciated by the critics in the ongoing dispute [2]. In my talk, I shall elaborate on this in simple qualitative terms. Of course, it may turn out that this new approach to IFE is not feasible because of practical experimental limitations. But as far as I can see, it does not violate basic fusion physics, as claimed by the critics. In any case, I expect that these ideas carry high potential for future high energy density research.

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Performance Limits for Magneto Inertial Fusion Reactors

Ronald Moses[1], *Kurt Schoenberg*[2]

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Magneto-Inertial Fusion (MIE) couples the inertial confinement of magnetoplasma pressure with the magnetic confinement of plasma thermal energy to potentially achieve fusion energy gain at plasma densities intermediate between magnetic (MFE) or inertial (IFE) fusion reactor concepts. Purported advantages of MIE include significantly reduced driver requirements compared to IFE systems and significantly reduced reactor size and plasma energy requirements compared to MFE concepts. The magnetic field that insulates plasma from its surroundings is an essential ingredient of MIE where thermal transport sets the requirements on driver technology and concomitantly, reactor economics. In this talk, we employ plasma thermal transport modeling, electrodynamics, and wall material properties to provide an assessment of the design space accessible for MIE reactors. Our model includes 1-D simulation of rotating, spherical, pressure-driven, inviscid liquid metal drivers. The plasmas are simulated in 2-D as both spheromaks and spherical tokamaks with finite beta. Thermal energy flows over and across magnetic flux surfaces according to tensor-based thermal conductivity, and magnetic flux diffuses into the resistive metallic wall. We. elucidate the strong coupling between plasma size and energy content, magnetic field and plasma confinement, implosion rate, flux loss and wall heating by diffusion, and drive power. This coupling, along with material constraints, then sets the bounds for fusion energy generation using MIE concepts.

Direct-Drive Inertial Confinement Fusion Studies for LMJ at CEA: Status and Prospect

BENOIT CANAUD[1]

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We present a review of our recent activities regarding direct-drive implosion and preparation of Inertial Confinement Fusion on the Laser MégaJoule Facility.
Various aspects will be addressed such as the sensitivity of the self-ignition threshold of direct-drive ICF targets to numerous physical phenomena such as hot-electron generated by two plasmons decay or how shock ignition can overcome the deleterious effects of these hot electrons. We will also address the solid-to-plasma transition and present new experimental results compared to theory. The transmission of the laser through a plastic solid planar target is shut down when 1w-incoming laser-intensity becomes greater 3x1011 W/cm2 in the experiment that is well recovered by numerical calculations. We will present also new results of direct-drive implosions done on OMEGA facility in two distinct regimes: an exploding pusher and a compressive hydrodynamics regime. These results will be compared to 2D/3D simulations done with the CEA hydrodynamics code.
Finally, we will present a study on direct-drive irradiation calculations that have led to a proposal of splitting the 60-beams OMEGA layout in two sub configurations of 24 and 36 beams each that have again a direct-drive irradiations.

FLAIM: A Volume Ignition Model for the Compression and Thermonuclear Burn of Spherical Fuel Capsules

Abd Essamade Saufi[1], *Sean Barrett*[1], *David Chapman*[1], *Nicolas Niasse*[1], *Nathan Joiner*[1]

[1]First Light Fusion

First Light Fusion (FLF) is a private company researching inertial confinement fusion (ICF) using a high-velocity projectile. Part of the FLF's current effort is devoted to the development of FuSE (FUsion System Evaluator), a fast and reliable end-to-end fusion system model employed to inform concept design of our planned ignition platform, the pulsed power facility Machine 4 (M4). In this context we present the "First Light Advanced Ignition Model" (FLAIM), one of the key components of FuSE: FLAIM is reduced ignition model, describing the compression and volume ignition of a spherical fuel

capsule surrounded by a heavy metal pusher. The design is based on the Revolver concept [1], which is well-known for its high hydrodynamic robustness at low temperature and rho-R and for its efficient radiation trapping. While hydro codes can be employed to simulate these systems in detail, they remain computationally expensive, especially for the systematic exploration of a very large design space (e.g., in a global optimiser). The crucial aspect of this model is the possibility to leverage the simplicity of the geometrical description to push the complexity of the physical modelling, keeping the computational cost low enough to be efficiently used in an optimisation algorithm. In contrast to previous works [2, 3], we employ a Lagrangian formulation for the description of the hydrodynamics and we refrain from making any assumption regarding the material properties (i.e., using a non-ideal EoS). We adopt a 3T description, in which the system is defined by separate electron, ion and radiation temperatures, the latter being set by Bremsstrahlung emission, Compton scattering and their inverse processes. Radiation and conduction losses are accounted for, tracking the Marshak wave position in the pusher and consistently evolving the wall temperature based on the flux at the interface [3]. The thermonuclear burn model includes the main branches of DT / DD reactions, alpha particle escape and fuel depletion. We compared FLAIM with our in-house hydro code B2 over a large parameter space, showing excellent agreement in terms of main profiles (temperatures, pressure, density), as well as key diagnostic such as neutron yield and burn fraction. This increases our confidence in the quality of the model for rapidly exploring potentially large design spaces and support important engineering decisions. The integrated capabilities and flexibility of FLAIM make it, to our knowledge, one of the most detailed reduced ignition models, offering an important support for the accurate design of ICF targets.

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Control of Parametric Instabilities in Inertial Confinement Fusion With Low-Coherence Lasers

Suming Weng[1], Hanghang Ma[1], Zhao Liu[1], Xiaofeng Li[2], Yuanxiang Wang[1], Zhengming Sheng[1], Jie Zhang[1]

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Parametric instabilities such as stimulated Raman scattering (SRS), stimulated Brillouin scattering (SBS) and two plasmon decay (TPD) are one of the most fascinating subjects in laser plasma physics. In particular, they may cause significant laser energy loss and produce harmful hot electrons to preheat fusion targets in laser-driven inertial confinement fusion (ICF). Therefore, the understanding and control of parametric instabilities are essential to the realization of laser fusion.

In this report, I will first briefly review the research background and basic physical process of the parametric instabilities. Then, our theoretical and numerical simulation results about the development of parametric instabilities in the interaction of a large-scale inhomogeneous plasma with a broadband laser pulse will be shown and compared with the latest experimental results [1,2]. Next, I will present an accurate mathematical model for describing broadband laser, and further generalize the model to describe sunlight-like laser with a certain bandwidth and random polarization. The mitigation of parametric instabilities using sunlight-like lasers will be discussed [3]. Finally, I will briefly discuss how to reduce the coherence of lasers by using plasma optical methods, such as the laser depolarization for the crossed laser beams in ICF [4].

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Investigation of Laser Plasma Instabilities Driven by 527 Nm Laser Pulses Relevant for Direct Drive Inertial Confinement Fusion

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[4]Focused Energy GmbH, TU Darmstadt

The demonstration of ignition and net energy gain at the National Ignition Facility has paved the way for inertial fusion energy. The recently established company Focused Energy has presented a concept to address the demands for an inertial fusion energy power plant, in particular a fusion gain that is sufficient to compensate for the electrical power consumption of the plant, stable long-term operation and cost efficiency. One aspect is the use of laser light with a wavelength of 527 nm instead of 351 nm to compress the fusion pellets, which has considerable benefits for a fusion power plant including lower facility costs and higher optics damage thresholds.
One of the scientific challenges especially for 527 nm light, are laser plasma instabilities (LPI) such as stimulated Brillouin scattering (SBS), stimulated Raman scattering (SRS), two-plasmon-decay (TPD) and cross-beam energy transfer (CBET) since they reduce the laser-energy coupling and may cause hot electron preheat of the fuel.
In this contribution we report on an extensive study of SBS and SRS using the frequency doubled kilojoule high repetition rate L4n laser at the Extreme Light Infrastructure (ELI) – Beamlines for plasma parameters entering a regime that is relevant for direct drive inertial confinement fusion. We scanned the laser intensity range of 0.5×10^{13}–$1.1 \times 10^{15}\, Wcm^{-2}$ with more than 1300 shots and measured the onset and growth of the instabilities with a high confidence level. This dataset will be used as a benchmark for extensive studies of LPI mitigation techniques.

A Parallel GPU Code for the Simulation of Laser Plasma Instabilities in Large Scale Plasmas With Kinetic Effects

Hanghang Ma[1], *Zhengming Sheng*[1], *Suming Weng*[1], *Jie Zhang*[1]

[1]Shanghai Jiao Tong University

Laser plasma instability (LPI) is crucial for the inertial confinement fusion (ICF) for it has remarkable influences on the laser energy deposition efficiency. Numerical simulations of LPI play important roles in revealing the complex physical mechanisms of LPIs, explaining the LPI relevant experiments, and further guiding the design of the fusion target to avoid LPIs. Due to LPI is a three wave coupling process, the precise simulations of LPI with kinetic effects require to resolve the laser period (around one femtosecond) and laser wavelength (less than one micron). In the practical experiments of ICF, however, LPIs develop in a spatial scale of several millimeters and a temporal scale of several nanoseconds. Therefore, the precise simulations of LPI under experimental scale (large scale) require a huge simulation cost and are hard to be carried out by present kinetic codes. In this paper, a full wave fluid model is constructed and solved by the particle-mesh method, which leads to the development of a 2D GPU code named as PM2D. Due to in the particle-mesh method, the macro particles can move freely within the fixed mesh grids, the PM2D code can simulate the kinetic effects of LPIs self-consistently as the frequently used particle-in-cell (PIC) codes at present. Moreover, for the physical model adopted in the PM2D code is specifically constructed for LPIs, the required macro particles per grid in the simulations can be largely decreased comparing with the PIC codes, which results in a much smaller simulation cost of the PM2D code. After the distributed computing is realized, our PM2D code is now able to run on GPU clusters with a total mesh grids up to several billions, which meets the total mesh grids requirements for the ICF experimental scale simulations of LPI. From the tests, the simulation speed of our PM2D code is about thirty times larger than the PIC code. Moreover, the numerical noise in our PM2D code is much lower, which makes it more robust than the PIC codes in the long time simulation of LPIs.

FuSE: A Rapid, Full-System Tool for Projectile-Driven Inertial Confinement Fusion Design and Optimisation

Dave Chapman[1], *Damilola Adekanye*[1], *James Allison*[1], *Luca Antonelli*[1], *Sean Barrett*[1], *Hannah Bellenbaum*[1], *Matthew Betney*[1], *Rafel Bordas*[1], *Teresa Delgardo*[1], *Thomas Edwards*[1], *Nicholas Hawker*[1], *Gwilym Jones*[1], *Thomas Kosteletos*[1], *Nicholas Niasse*[1], *James Pecover*[1], *Abd Essamade Saufi*[1], *Nathan Joiner*[1]

[1]First Light Fusion Ltd

First Light Fusion is pursuing a unique, projectile-driven route towards inertial confinement fusion. Our next machine (M4) will be the world's largest pulsed power facility, with the specific aim of demonstrating ignition in a spherical volume ignition target using our uniaxial driver and proprietary hydrodynamic amplification technology. In order to derisk the capital investment of such a large and costly facility, we are making use of cutting-edge robust optimisation techniques coupled to a simplified, holistic modelling framework to provide a rapid, iterative design capability. Our Fusion System Evaluator (FuSE) tool combines strongly assured, simplified models of each of the major components of the proposed M4 machine: the pulsed power system, magnetically accelerated flyer load, hydrodynamic amplifier and fuel capsule implosion, ignition and burn.

In this talk, we will present the FuSE tool and its application in producing our sixth (and most current) major M4 design point iteration (DP6). A physics description of the main model components will be given and the application of a robust optimisation under uncertainty workflow will be given. The optimisation is performed using conservative estimated model uncertainty distributions and consider an objective which gives primacy to maximising the chances of fusion ignition, rather than more traditional goals, such as fuel gain or neutron yield. Global sensitivity analysis performed around DP6 shows that amplifier design choices and the microphysics of burning DT plasma are the most impactful uncertainties, highlighting a need for enhanced interactions and collaborations.

Backward Scattering of Laser Plasma Interactions From Hundreds-of-Joules Broadband Laser on Thick Target

Peipei Wang[1], *Chen Wang*[1]

[1]Shanghai Institute of Laser Plasma

Laser plasma interaction (LPI) is one of the key issues in laser-driven inertial confinement fusion ignition (ICF), as it may affect target compression and fusion energy gain. Broadband laser technology is one novel option that may inhibit the related processes of LPI. It can be thought of a decrease of the effective light intensity felt in the plasma, which in turn may play a role in inhibiting the occurrence and development of related LPI processes in the plasma.
One broadband double-frequency laser with an output energy of hundreds of joules by using the superluminescent diode (SLD) technology has now been built by the researchers from Shanghai Institute of Laser Plasma. The experiment in this study was conducted using a single-beam 2w laser with broadband or narrowband characteristics to drive a C8H8 plane-thick target. A long-pulse (3ns) laser initially ablated the target to generate plasma. Therefore, it continued to interact with the continuously generated plasma to trigger the occurrence and development of LPI-related processes. The thickness of the target was 300 μm, thick enough to avoid being burnt during the pulse cycle of the 3 ns laser.
Through a comparison with the results for a traditional narrowband laser under the same parameter conditions, we initially determined that the broadband laser had a clear suppression effect on both the BSBS and BSRS under a laser intensity of less than 1 × 1015 Wcm-2. Both BSBS and BSRS made a lower contribution and exhibited a slower increase under increasing laser intensity. An abnormality in the hot-electron energy spectrum was observed under broadband laser driving, possibly attributable to the fact that a broadband laser is more likely to induce parametric decay instabilities. Finally, as a new low-coherence driver, this broadband laser significantly differs from traditional narrowband laser drivers. The results reflect the contributions of broadband lasers in suppressing LPI-related

processes, which may provide a basis for the fundamental understanding of broadband lasers, as well as an in-depth understanding of LPIs.

The ELI-Germany Laser-Induced-Fusion Project

Luca Volpe[1]

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Laser induced fusion (LIF) has been demonstrated reaching ignition and burn, with a net energy gain equal to 1.5. The recent results in the US have shown clearly that laser-fusion ignition is indeed possible, predictable, and repeatable. This breakthrough has greatly increased interest in laser fusion of many countries, universities, research centres and private companies. Together with magnetic confinement fusion the Inertial Confinement Fusion is now a promising approach for the construction of a fusion power plant. Europe has a window of opportunity to be a relevant player in such changes by involving the scientific community, industries and the relevant institutions.
The Extreme Light Infrastructure (ELI) has started a dedicated project to explore the role ELI could play in enabling the development of methods or technology relevant to LIF, particularly, but not exclusively, with key relevant actors in the German research community. This initiative is a first step in the context of wider European activities in this domain, exploring opportunities and determining priorities for technical development with a perspective of launching a wider call for Mission-based access to ELI and ultimately contributing to practical ways to generate laser-based clean energy.
As a first step in this initiative a kick-off-project meeting was organised in November 2023
at the ELI Beamlines Facility near Prague, Czech Republic.
In the talk the main lines of actions of the LIF project will be presented.

Wednesday (January 31st)

Start	Duration	Speaker	Title
Session 7: Laser-Ion Acceleration (Chair: J. Ren)			
08:30	0:20	PUKHOV, Alexander	Peeler Regime of Laser-Plasma Interaction: Electron and Ion Acceleration, X-Ray Emission
08:50	0:20	GEULIG, Laura	Laser-Driven Acceleration of Gold Ions at the Centre for Advanced Laser Applications
09:10	0:20	HONRUBIA, Javier	Proton Beam Generation for Fast Ignition of Inertial Fusion Targets
09:30	0:20	REICHWEIN, Lars	Collisionless Shock Acceleration of Spin-Polarized 3He
09:50	0:20	SCHOLLMEIER, Marius	Experimental Evaluation of Nanorods Interacting with Ultra-Short High-Power Laser Pulses
10:10	**00:30**	**Coffee break**	
Session 8: Electron Acceleration (Chair: A. Pukhov)			
10:40	0:20	REN, Jieru	Brilliant Electron Beam Generation Through Laser-NCD Plasma Interactions
11:00	0:20	KALLA, Réne	Experimental concept for the detection of fission isotopes of 238U, produced by laser-driven gamma rays
11:20	0:20	LE PAPE, Sebastien	The Apollon Research Infrastructure: a Journey to a Multi-PetaWatt Multi Beam Laser Facility
11:40	0:20	KUSCHEL, Stephan	Orbital Angular Momentum Beams for Laser Driven Particle Acceleration
12:00	0:20	KARSCH, Stefan	Multi-GeV Monoenergetic Electron Beams from an Optical Shock Front Accelerator
12:20		**Lunch break**	
17:00	**1:30**	**Poster Session**	
18:40	**00:20**	**Conference Board Meeting**	
20:00		**Conference Dinner at Birkenhöhe**	

Peeler Regime of Laser-Plasma Interaction: Electron and Ion Acceleration, X-Ray Emission

Alexander Pukhov[1], *Xiaofei Shen*[2]

[1]Uni Dusseldorf
[2]Heinrich-Heine-Universität Düsseldorf

We discuss relativistic laser interaction with overdense plasmas, where the laser pulse is incident parallel to the plasma surface, the so-called “peeler” regime. In this scheme, the laser pulse impinges on an edge of a tape or on a sharp edge of a bulk target. The edge allows for an efficient conversion of the laser pulse into a surface plasma wave (SPW). The SPW propagates along the target surface. Its transverse electric field extracts dense buckets of electrons into the nearby vacuum region. The longitudinal electric field of the SPW accelerates the se electrons along the surface. Thus, a large fraction of electrons (tens of nC) from the target skin layer can be “peeled” off and accelerated to high energies.
These electrons wiggle in the combined quasistatic transverse electric and magnetic fields at the target surface and emit bright betatron radiation. Using fully three-dimensional particle-in-cell simulations, we show that a tabletop 100 TW class femtosecond laser can produce an ultrabright hard x-ray pulse with 1011 photons, flux up to 10^7 photons/eV and brilliance about 10^23 photons/s/mm2/mrad2/0.1%BW by irradiation of an edge of a microtape target.
When these peeled off energetic electrons arrive at the rear edge of the tape, a longitudinal bunching field is established. Protons are simultaneously accelerated and bunched by this field, leading to a highly monoenergetic proton beam.

Laser-Driven Acceleration of Gold Ions at the Centre for Advanced Laser Applications

Laura Desiree Geulig, *Veronika Kratzer*[1], *Erin Grace Fitzpatrick*[1], *Maximilian Weiser*, *Runjia Guo*[1], *Ming-Yang Hsu*[1], *Peter Thirolf*[2]

[1]LMU Munich
[2]Ludwig-Maximilians-Universität München

The efficient acceleration of gold ions is a first step towards the ‘fission-fusion’ reaction mechanism, which aims at investigating the rapid neutron capture process, by using laser-accelerated heavy ions in a sandwich target configuration [1]. At the Centre for Advanced Laser Applications (CALA) we accelerated highly charged gold ions using the ATLAS-3000 laser (central wavelength 800 nm, pulse length 25 fs, energy per pulse < 60). The laser is focused by an f/2 off-axis parabola onto gold foils with thicknesses ranging from 200 nm to 500 nm. The ion spectra are analyzed using a Thomson parabola spectrometer specifically designed for heavy ions. The diagnostics include CR-39 track detectors as well as a setup for online readout employing a lanex screen in combination with an sCMOS camera. Spectroscopically controlled radiative heating is integrated into the setup, which allows the removal of (carbo-hydrate) contaminants present on the surface of the target foils, and thus aids in increasing the yield and the energy of the heavy ions [2].

Proton Beam Generation for Fast Ignition of Inertial Fusion Targets

Javier Honrubia[1], *Alfonso Mateo*[1], *Paul Gibbon*[2], *Valeria Ospina*[2], *Deborah Callahan*[3], *Pravesh Patel*[3], *Markus Roth*[4]

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[3]Focused Energy Inc.
[4]Focused Energy GmbH, TU Darmstadt

Ion fast ignition is an alternative for igniting thermonuclear fuels with lower laser energy and drive symmetry requirements [1,2]. The ion beam characteristics estimated for fast ignition so far are based on strong assumptions about beam focusing and ideal beam-plasma interaction. However, new effects have been reported, such as the divergence of laser-driven protons generated in hollow cones [3,4] and its consequences on ion beam energy deposition [5].
We have conducted integrated simulations of proton fast ignition by combining PIC, hybrid, and radiation-hydrodynamic calculations. Here, we analyse proton acceleration by two-dimensional PIC simulations of scaled-down cones. A special design of the cone and the laser pulse reduces the beam divergence. The acceleration of ions heavier than protons also contributes to lowering it. Preliminary simulations with mm-scale cones have also been performed to investigate the dependence of return currents and associated kilo-Tesla magnetic fields on the target dimensions.
The proton distribution function obtained from PIC calculations has been used to conduct hybrid simulations coupled to radiation-hydrodynamics and ignition physics. The goal has been to get realistic laser energy requirements to fast ignite imploded fuel configurations, which may help assess the potential of proton-fast ignition as an alternative scheme for Inertial Fusion Energy.
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Collisionless Shock Acceleration of Spin-Polarized 3He

Lars Reichwein[1], *Xiaofei Shen*[1], *Markus Büscher*[2], *Alexander Pukhov*[3]

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[3]Uni Dusseldorf

While the acceleration of spin-polarized ions from laser-plasma interactions has recently been experimentally verified [1], it has become clear that maintaining a high degree of polarization strongly depends on presence of inhomogeneous electromagnetic fields during the acceleration process. Thus, applications with high laser intensity require elaborate acceleration schemes to prevent significant depolarization.
In this talk, we present an acceleration scheme for spin-polarized ^{3}He in the regime of $a_0 = 100 - 200$. Our setup utilizes a solid Carbon foil in front of the near-critical Helium target. The laser pulse heats up the Carbon foil, inducing subsequent Collisionless Shock Acceleration of the Helium ions [2].
Our particle-in-cell simulations show that polarization on the 90%-level and energies in the range of hundreds of MeV are achievable using this mechanism. This is a strong improvement over the lower polarization obtained in Magnetic Vortex Acceleration, even at lower laser intensities [3]. We further are able to show that the radiation reaction force leads to increased beam charge due to an improved matching of the trapping condition for the shock wave.

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Experimental Evaluation of Nanorods Interacting With Ultra-Short High-Power Laser Pulses

Marius Schollmeier[1], Marc Günther[2], Naveen Yadav[2], Hartmut Ruhl[2], Georg Korn[3]

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[2]Marvel Fusion GmbH
[3]Marvel Fusion

Intense, ultrahigh-contrast, short laser pulses interacting with embedded, nanostructured materials in a mixed fuel matrix offer feasible options for a novel Inertial Confinement Fusion (ICF) concept with improved commercial viability [1]. The nanostructures enable ultrahigh power absorption capabilities and can efficiently transfer large fractions of laser energy to the ions on a 100-fs timescale, accelerating the ions to MeV energies [2]. The accelerated ions are then used to rapidly heat layers of mixed fuels to fusion conditions exceeding energy losses on time scales orders of magnitude shorter than the available confinement time. The operation of such a Nano Accelerator requires laser-irradiation with high intensity (I > 10^{20} W/cm^2), ultra-high-contrast (<10^{-12} on ps timescales), sub-100-fs laser pulses at sub-micrometer wavelength. Future commercial applications additionally require efficient laser pulse generation with above-10% wall plug efficiency and operating at 10 Hz [3].

With regards to realizing such an ICF concept, Marvel Fusion has performed or is performing contrast and intensity-improving measures at petawatt facilities in Europe as well as the U.S. Excellent laser temporal contrast combined with high focused intensity was demonstrated via volumetric ion acceleration from few-nm-thin foil targets as well as from nanowire array targets. We present our experiment roadmap towards validating the Nano Accelerator that is core to our fusion approach, as well as experiment results from several campaigns aimed at characterizing laser- and target performance at petawatt laser facilities both in the U.S. as well as in Europe.

References:
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[2] Y. Nadav et al., see this workshop
[3] G. Korn, et al., see this workshop

Brilliant Electron Beam Generation Through Laser-NCD Plasma Interactions

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We experimentally generated brilliant electron beams through picosecond-laser-NCD (near critical density) plasma interactions. The NCD plasma sample (T 17 eV, n 4e20/cc) was created through heating a foam target with nanosecond-laser-induced hohlraum radiation in the soft x-ray regime. Measurements with 3-15 ns time delays between the ps laser and ns laser were investigated. The electron beam has a Maxwellian distribution with temperature of about 12 MeV and cutoff energy near 90 MeV. The charge quantity is about 90nC for electrons with energy larger than 1MeV. The half divergence angle is about 11 degree. Comparatively, the electrons beams, that were generated through laser interaction with cold foam, have much broader distributions with hollow structure transversely. Supported by the particle in cell simulation, the hollow distribution was attributed to the filamentation of laser beam interacting with porous-structure foam, while in homogeneous plasma, both the laser and the electron beam will be very well collimated.

Experimental Concept for the Detection of Fission Isotopes of 238U, Produced by Laser-Driven Gamma Rays

René Kalla[1], Pascal Boller[2], Alex Zylstra[3], Jeff Burggraf, Christian Brabetz[2], Jan Glorius[2], Mikhail Gyrdymov, Johannes Hellmund[2], Johannes Hornung[2], Yury Litvinov[2], Paul Neumayer[2], Parysatis Tavana[4], Olga Rosmej[2], Vincent Bagnoud[2], Dieter Schneider[5], Thomas Kühl[6]

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The rapid developments in laser acceleration of highly-energetic charged particles and the production of gamma-rays and neutrons as secondary beams provide a basis for novel nuclear physics experiments. Because of the pulsed nature of the particle generation and its ultrashort timescales, the laser-matter interaction is able to generate ultra-high peak fluxes of particles and radiations. These fluxes are very short in time and constrained spatially and they exceed the capabilities of standard particle accelerators by orders of magnitude. They are particularly interesting in the field of nuclear astrophysics, for medical applications as well as in inertial confinement fusion research.

This newly emerging field is called nuclear photonics, which includes among others the study of laser-driven nuclear reactions. However, traditional detection methods used in nuclear spectroscopy cannot be applied directly in such experiments. Here, the laser-matter interaction generates a strong gamma-flash and an electromagnetic pulse (EMP), which can lead to measurement noise or even detector failure. The protection of the detection system against these effects is especially important for short-lived nuclides, when the detection cannot be time-gated easily. As a first mitigation method, the distance to the interaction location can be increased to protect the detection system, because the intensity of the radiation decreases quadratically with the distance. Additionally, a Faraday cage can be used for detector shielding against EMP. We already demonstrated a functional detection setup in a laser-driven nuclear experiment in September 2019[1] and December 2021, where fission products generated by laser-accelerated protons impinging on ^{238}U targets were successfully transported and detected in a germanium-based gamma spectrometer.

In this contribution, we would like to report on an experiment in which we successfully detected fission products of ^{238}U produced by high-energy gamma rays at the PHELIX facility. The gamma rays are obtained through bremsstrahlung of high-energy electrons in a high-Z converter target [2,3]. Low density foams turned into a near-critical-density plasma by a laser pre-pulse provided the conditions for excellent conversion efficiency of the laser energy into directed high-energy electrons[2]. For this experiment, the gas transport system has been further improved in speed, offering the possibility to detect isotopes with lifetimes below 40 sec. Details on the detection system and detected isotopes will be presented.

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The Apollon Research Infrastructure: A Journey to a Multi-PetaWatt Multi Beam Laser Facility

Sebastien Le Pape[1]

[1]Ecole Polytechnique

to follow

Orbital Angular Momentum Beams for Laser Driven Particle Acceleration

Stephan Kuschel[1]

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Orbital angular momentum (OAM) beams, or optical vortices, have shown to spin obejcts under the microscope, allow for rotational frequency shifts and are used STED microscopy to beat the abbe resolution limit. Creating an OAM beam and focusing it to relativistic intensity offers new possibilities for particle acceleration and may also change the coupling of the laser into the plasma.

In this talk I will present an experiment which shows that electron acceleration with an OAM beam is possible. I will also discuss further developments and discuss other uses of such beams in the laser plasma community.

Multi-GeV Monoenergetic Electron Beams From an Optical Shock Front Accelerator

Stefan Karsch[1]*, Katinka von Grafenstein*[2]*, Felipe Cezar Salgado*[3]*, Florian Moritz Foerster*[2]*, Johannes Zirkelbach*[2]*, Jinpu Lin*[2]*, Nils Weisse* [2]*, Florian Haberstroh*[2]*, Faran Irshad*[2]*, Enes Travac*[2]*, Jannik Esslinger*[2]*, Andreas Döpp*[4]*, Karl Matthäus Zepf*[5]

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Laser-accelerated electron beams have been the subject of intense research in the last few decades. The general direction in the field is the development towards ultralow beam emittance, necessitating controlled injection methods to ensure electron trapping in the laser-driven plasma wave. The most popular injection mechanism, due to its simplicity and flexibility, involves a density shock wave oriented perpendicular to the wakefield propagation direction. Upon crossing this shock wave, the plasma wave breaks and locally injects a bunch of electrons, leading to quasi-monoenergetic electron bunches due to the uniform acceleration distance for all particles. A main drawback of this scheme is the fact that this braking wave injects the electrons into a phase of the wake that is close to the zero-field crossing, leading to a significantly reduced electron energy compared to an untriggered self-breaking injection scheme with broadband pulses. The consequence has been an energy limit of approx. 1 GeV for such shock-injected bunches. With a novel optical method to generate the shock, we can gain additional degrees of freedom allowing to shift the injection point more into the high-field phase of the plasma wave. Using this approach, we have recently demonstrated 2-2.5 GeV, monoenergetic electron beams from our ATLAS laser facility. In a second experiment, we implemented machine learning methods to optimize the laser and plasma parameters automatically to yield electron beams with a pre-selected energy.

Thursday (February 1st)

Start	Duration	Speaker	Title
Session 9: Proton Beamlines (Chair: G. Xiao)			
08:30	0:20	FREEMAN, Matthew	Proton Radiography at LANSCE over the Next 10 Years
08:50	0:20	SCHANZ, Martin	PRIOR-II – Towards Probing of HE Driven Shock Wave Experiments
09:10	0:20	DEWITT, Daniel	Capture and Transport of High-Energy Laser Accelerated Ions
09:30	0:20	GRIMM, Sarah	Towards Stopping Power Experiments With LIGHT
09:50	0:20	SCHMIDT, John	The LANL Proton Radiography Facility and Investigations Toward Achromatic Imaging
10:10	**00:30**	**Coffee break**	
Session 10: Laser Technology and Targetry (Chair: Z. Major)			
10:40	0:20	HORNUNG, Johannes	Synchronized Off-Harmonic Probe Laser with Highly Variable Pulse Duration for Laser–Plasma Interaction Experiments
11:00	0:20	SEUPEL, Thomas	Development of a High Repetitive Target for Laser Driven Radiation Sources
11:20	0:20	BAGNOUD, Vincent	Temporal-Contrast Improvements and Current Limits at PHELIX
11:40	0:20	RAMAKRISHNA, Bhuvanesh	Probing Bulk Electron Temperature via X-Rays in a Solid Density Plasma
12:00	0:20	FÖLDES, Istvan	Temporal Pulse Cleaning by Fourier Filtering: from the UV to the Infrared
12:20		**Lunch break**	
Session 11: Phase Transitions and Lab Astro (Chair: B. Rethfeld)			
17:00	0:20	LIPP, Vladimir	Non-Thermal Structural Transformation of Diamond Driven by X-Rays
17:20	0:20	LÜTGERT, Julian	Temperature and Structure Measurements of Heavy-Ion-Heated Diamond Using in Situ x-Ray Diagnostics
17:40	0:20	BISTONI, Oliviero	Electron-Phonon Coupling in Warm Dense Metals
18:00	0:20	SCHREINER, Stephan	Grating-Based Phase-Contrast Imaging of Laser-Driven Shock-Waves
18:20	0:20	FILINOV, Alexey	Ab Initio Approach to Static and Dynamic Properties of Partially Ionized Plasmas and Strongly Coupled Uniform Liquids of Charged Fermions
18:40	0:20	RETHFELD, Bärbel	Ultrafast Melting of Copper: Experiment and Theory

Proton Radiogrraphy at LANSCE Over the Next 10 Years

Matthew Freeman[1], *John L IV Schmidt*[2]

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[2]Los Alamos National Laboratory

The LANSCE proton radiography facility has been in operation now for more than 20 years. It is now at a state where it is oversubscribed, and ready to grow in line with upgrades proposed for LANSCE. This includes the potential siting of a second pRad facility with new capabilities, and, longer term, an upgrade to LANSCE's endpoint energy that could be harnessed to visualize thicker materials in higher fidelity. Preliminary notions for these plans will be discussed.

PRIOR-II – Towards Probing of HE Driven Shock Wave Experiments

Martin Schanz[1], *Roman Belikov*[2], *Matthew Freeman*[3], *Fesseha Mariam Mariam*[4], *John L IV Schmidt*[3], *Dmitry Varentsov*[1]

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[2]Goethe-Universität Frankfurt am Main
[3]Los Alamos National Laboratory
[4]LANL

Magnetic lens-based proton radiography is a powerful diagnostics technique capable of resolving ultra-fast processes on the ns scale in dense matter with unprecedented micrometer spatial resolution. In addition to those optical benefits, it is furthermore capable of resolving the dynamic areal density distribution of the target or process investigated with sub-percent accuracy making it an ideal diagnostic for HED physics applications or material science.

While the PRIOR-II facility (Proton Radiography for FAIR) at GSI was originally designed for 2-4.5GeV proton beams, the feasibility of imaging using heavier ions (up to 975MeV/u 12C6+ and up to 1.5GeV/u 14N7+) was investigated during the 2023 engineering run to circumnavigate future shock wave experiment proposal rejections solely due to the low demand and therefore availability of proton beams at GSI. Despite an expected decrease in spatial resolution performance due to increased energy loss straggling, the heavy ions proved suitable for imaging purposes resulting in the demonstration of the world's first heavy ion radiography and even showed a greater density resolution capability due to simultaneously increased target scattering. Due to the availability of lower energy beams, this concept was also tested and demonstrated for possible future medical applications with 300MeV/u 12C6+ and a novel 225MeV/u 4He2+/12C6+ mixed-ion-species beam suitable for simultaneous patient treatment and in-vivo position verification.

Furthermore, in preparation for a series of planned shock wave experiments with HE drivers starting in 2025 with the upgrade of the existing HHT experimental area at GSI for HE experiments, preliminary measurements for the assessment of the SIS-18 4H4 extraction scheme stability with 2.5GeV protons were performed.

Capture and Transport of High-Energy Laser Accelerated Ions

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[3]Extreme Light Infrastructure - Nuclear Physics (ELI-NP)

The emergence of laser-accelerated ions has created a need for innovative approaches in capturing and transporting ion beams, diverging from methods applied on more conventional beam characteristics. Using existing TNSA (Target Normal Sheath Acceleration) experimental data from GSI and employing novel simulation approaches, this project aims to develop a faster, parameter-driven optimisation process, thus minimising the alignment time and offering new insight when designing new beamlines.

The initial phase involves reconstruction of the particle distribution after the target to be used in simulations of the capture and transport using PIC (Particle In Cell) codes, such as ASTRA, to quantify space charge effects. The impact of space charges is inversely proportional to energy, suggesting that disregarding this effect at higher energies during later transport stages could conserve computational resources. Following experimental validation, the simulation will incorporate an optimisation layer in order to provide automated alignment and parameter recommendations, focusing on improving beam quality characteristics like emittance, energy spread, and transmission.

Furthermore, the project will explore advanced focusing elements, including superconducting solenoids and plasma lenses, in its simulations. This addition not only aims to enhance existing beamlines but also to conceptualise potential future upgrades, broadening the scope and impact of the research.

Towards Stopping Power Experiments With LIGHT

Sarah Jane Grimm[1], Haress Nazary, Martin Metternich[2], Dennis Schumacher[2], Abel Blazevic[2], Florian-Emanuel Brack[3], Florian Kroll[4], Christian Brabetz[2], Ulrich Schramm[5], Vincent Bagnoud[2], Markus Roth[6]

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The primary objective of the Laser Ion Generation, Handling and Transport (LIGHT) beamline at GSI Helmholtzzentrum für Schwerionenforschung GmbH is to manipulate the phase-space of laser-generated ion beams and to couple them into conventional accelerator structures. In recent years, the LIGHT collaboration has successfully generated and focused high-intensity proton bunches with an energy of 8 MeV and a temporal duration shorter than 1 ns (FWHM) [1].

A compelling application of these short ion bunches is the investigation of the ion-stopping power in plasmas. Gaining a precise understanding of the energy deposition of ions in dense plasmas is pivotal for consolidating existing theories and, furthermore, holds significance in advancing inertial confinement fusion [2]. The highest discrepancies in stopping power theories occur in the regime where $v_{\text{projectile}} \approx v_{\text{thermal,e}}$. In this regime, the interaction between the projectile ions and the plasma electrons increases substantially, leading to significant electron coupling and electron degeneracy [3]. Since conclusive experimental data is scarce in this regime, we plan to conduct experiments on a laser-generated plasma probed with ions generated using the LIGHT beamline. When probing laser-generated plasmas with accelerator beams, maintaining a probe beam duration within a timeframe, where uncertainties due to averaging over fast-changing plasma parameters are minimal, is crucial [4]. Therefore, the temporal length of the plasma-probing ion bunches should be as short as possible.

To reach higher temporal resolutions than previously achievable, while fulfilling the velocity matching request $v_{\text{projectile}} \approx v_{\text{thermal,e}}$, our recent studies have dealt with ions of lower kinetic energies. In 2021, laser accelerated carbon ions were successfully transported with two solenoids and focused temporally with LIGHT's radio frequency cavity. A pulse length of 1.2 ns (FWHM) at an energy of 0.6 MeV/u was achieved. Similarly, in 2022, protons with an energy of 0.6 MeV/u were transported and temporally compressed to a pulse length of 0.8 ns [5].

For the stopping power experiment in January 2024, both carbon ions and protons will be used to probe a plasma. This plasma will be generated by a nanosecond laser (*nhelix*). Hydrodynamic simulations suggest that the plasma parameters change on a timescale compatible with the duration of the probing ion beams. To verify this, the free electron density of the plasma will be measured using interferometry. This recently added on-shot diagnostic tool was tested in a beamtime in 2023 [6].

In my talk, I will introduce the stopping power experiment, demonstrate its feasibility based on simulations and findings obtained from preparatory beamtimes and report on the latest results.

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The LANL Proton Radiography Facility and Investigations Toward Achromatic Imaging

John Schmidt[1], *Fesseha Mariam*[2]

[1]Los Alamos National Laboratory
[2]Los Alamos National Laboratories

Proton radiography (pRad) at LANL is an imaging modality best suited for imaging dense materials up to 50 g/cm-2 at time scales of 100 ns. The temporal structure of the LANSCE 800 MeV proton beam allows the flexibility for multi-frame imaging over the duration of dynamic processes lasting
up to 20 microsec or more. The LANL pRad facility has so far provided invaluable data on dynamic processes such as explosives and explosives-driven shock in materials. However, it is limited by chromatic effects that degrade the resolution of off-energy protons. Work currently underway aims to
eliminate or mitigate these chromatic effects using a second-order achromatic magneto-optic imager. Our
team aims to design, fabricate and test such an imager using low-energy electron beams (25MeV) at the
Idaho Accelerator Center. If successful, this will serve as a prototype that can be scaled up for use with
800-MeV protons. We will discuss the benefits and complexities of achromatic imaging over existing capabilities.

Synchronized Off-Harmonic Probe Laser With Highly Variable Pulse Duration for Laser–plasma Interaction Experiments

Johannes Hornung[1], *Yannik Zobus*[1], *Hugo Lorenté*[2], *Christian Brabetz*[1], *Bernhard Zielbauer*[1], *Vincent Bagnoud*[1]

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A prerequisite for accurately describing laser-plasma interaction experiments is a precise control of the plasma conditions, which in turn requires an accurate measurement of the on-shot plasma properties and dynamics. This is not only relevant for laser-solid interaction experiments, but also for experiments using undercritical or even near-critical density targets. To this end, popular plasma probing techniques include interferometry or shadowgraphy using short, sub-picosecond laser pulses or streaked shadowgraphy to measure the dynamics of the plasma on a nanosecond timescale. However, performing such measurements is difficult and either requires laser pulses with a short or long duration, depending on the measurement setup. A straightforward and widespread method utilizes a leakage of the main laser pulse as a probe beam. This approach usually does not allow

for an adaptable pulse duration, and additionally, the measurement signal is accompanied by a substantial background due to the main laser pulse. Frequency conversion of the probe beam does not fully resolve this problem, as the interaction of the main laser pulse with the plasma generates harmonics, contributing to the strong background in the interaction region. This effect can be reduced by using an off-harmonic probe beam, eliminating the spectral overlap with the main laser pulse. Possible solutions relies on standalone off-harmonic laser systems, which have to be synchronized by electronic timing systems or by frequency shifting a leakage pulse before amplification. Until now, these experimental realizations were limited to a given pulse duration of the probe beam or offered only a small variation of it. Therefore, a versatile laser to be used as a plasma probe needs to be synchronized with the main pulse, have an off-harmonic center frequency, and preferably have a variable pulse duration to combine it with different detection methods.
In this work, we present the development and experimental validation of a fully-synchronized off-harmonic laser system designed as a probe for ultra-intense laser plasma interaction experiments at the PHELIX facilty. The system exhibits a novel seed-generation design, allowing for a variable pulse duration spanning over more than three orders of magnitude, from 3.45 picoseconds to 10 nanoseconds. This makes it suitable for various plasma diagnostics and visualization techniques. In a side-view configuration, the laser was employed for interferometry and streaked shadowgraphy of a laser-induced plasma while successfully suppressing the self-emission background of the laser plasma interaction, resulting in a signal-to-self emission ratio of 110 for this setup. These properties enable the probe to yield valuable insights into the plasma dynamics and interactions at the PHELIX facility and to be deployed at various laser facilities due to its easy-to-implement design.

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Development of a High Repetitive Target for Laser Driven Radiation Sources

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Laser driven radiation sources have successfully demonstrated particle acceleration in the MeV ranges through TNSA [1]. With the increasing laser intensity state of the art laser system s are also increasing in repetition rate [2]. Due to this solid target designs come to their limit either due to mechanical stress from the changing speeds or due to the target number limit [3].

To overcome these limits different liquid targets that regenerate with a matching frequency under vacuum conditions are developed to enab le stable long time operation [4,5]. To this end a Liquid Leaf target system using water has been developed that in its first iteration stage presents a proof of concept device . A successful experiment of the first Liquid Leaf has already been demonstrated by D. Hofmann.

We will present the method of how the current Liquid Leaf can be characterized to find quantifiable stabilization parameters , with the intention to understand stability ranges. This knowledge will help to bui ld up optimize and in the final step completely automize a second generation Liquid Leaf that will be specifically used in an upcoming 100 Hz laser system. A tool to explore these improvements of the Liquid Leaf are hydrodynamic Openfoam simulations. Some tested models will be presented, and the current status will be shown.

To elucidate possible applications, we will present the main economical application , neutron radiography and an upcoming experimental test of electrical components and solar cells for radiation damage more in detail.

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Temporal-Contrast Improvements and Current Limits at PHELIX

Vincent Bagnoud[1], Christian Brabetz[1], Zsuzsanna Slattery-Major[1], Simon Röder[1], Bernhard Zielbauer[1], Yannik Zobus[1]

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The temporal contrast of short laser pulses plays an important role in laser-plasma experiments, because material ionization happens at intensities that are more than 10 orders of magnitude below the peak intensity of the laser pulse, which imposes a control of the pulse-intensity profile over at least the same dynamic range. There exist several sources for temporal-contrast degradation along a laser-amplification chain, which yield different features on the temporal profile and the community is very active on studying and proposing technical solutions to handle these problems.

At PHELIX, we have implemented several measures to ensure the highest temporal fidelity in laser amplification. This starts with reducing the temporal noise background via the generation of temporal-noise-free high-energy seed pulses through nonlinear parametric amplification. Here, we were able to improve the system reliability by substituting the first stage of amplification in the CPA chain by a temporal-noise-free amplifier, which solves some of the temporal-contrast issues while avoiding adding complexity to the system. More recently, we have been working on the coherent temporal contrast degradation, which shows up in the form of a slow rise of the temporal intensity of the laser pulse on the time scales of several 10's of picoseconds. This feature is present nearly universally in CPA laser systems worldwide and it remains very hard to control, until now.

In this contribution, we will report on experimental work done at the PHELIX facility to support our theory that the coherent contrast degradation is due to the combined actions of optical surface and laser beam imperfections. Following this analysis, we were able to derive a simple formulation of the temporal contrast, which we could verify experimentally at PHELIX. We believe that this new insight into the origin of temporal contrast could be used to have a more global approach to the analysis of temporal-contrast degradation, where our new findings underline the underestimated role of spatial beam quality on the temporal contrast in CPA lasers.

Probing Bulk Electron Temperature via X-Rays in a Solid Density Plasma

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The interaction of intense, ultrashort-duration laser pulses with matter provides the possibility to generate plasmas at solid-state density at high temperatures. Under these conditions the ion coupling parameter Γ [1] exceeds one and the plasma is thus in a strongly coupled state [2]. Such warm dense plasmas are of particular interest in inertial confinement fusion (ICF) and astrophysics [3]. For example, it is possible to study the X-ray opacity of matter under conditions found in stellar interiors [4]. High energy- density laser-produced plasmas offer a unique window for investigation of thermal equilibration between electrons and ions in strongly coupled plasma.

Mechanisms leading to forward accelerated, high quality ion beams, operating at currently accessible laser intensities in laser-matter interactions, are mainly associated with large electric fields set up at the target rear interface by the laser-accelerated electrons leaving the target. In this talk we discuss about the bulk electron temperatures calculated for thin Cu targets interacting with petawatt class Vulcan laser from the K α yield obtained using Highly Oriented Pyrolytic Graphite (HOPG) crystals. A core temperature of 30-40 eV extends homogeneously up to ten times the laser focal spot size. A strong correlation between the radial distributions of the bulk electron temperature, emission size and K α yield is observed. Results for the first time confirm variation in bulk electron temperature of targets dependent on polarization of the incident laser.

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Temporal Pulse Cleaning by Fourier Filtering: From the UV to the Infrared

Istvan Földes[1], Márk Aladi[1], Rita Dajka[2], Miklós Kedves[1], Tamas Nagy[3], Sándor Szatmári[2]

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Contrast requirements are key issues for ultrashort, high-power laser pulses necessitating more than 10 orders of magnitude temporal contrast to provide clean conditions for laser-matter interactions. Recently a new method based on Fourier filtering was developed [1] and successfully applied in a high-brightness KrF laser system [2], resulting in extreme high accelerations under clean experimental conditions [3]. The basis of Fourier-filtering is an intensity dependent phase shift introduced between the 0th and the higher diffraction orders in the focal (Fourier) plane of an annular beam, leading to time-dependent directional properties of the beam. This makes possible to efficiently remove the temporal noise by the use of a conjugated spatial filter pair. In contrast to plasma mirrors, the performance of Fourier filtering is not limited to the two orders of magnitude range of contrast improvement, but similarly to that, it can also be situated at the end of the amplifier chain. We report experiments which have been carried out with a Ti:sapphire system, using 40 fs, infrared pulses. The phase shifting effect of Fourier filtering and the resulting directional modulation of the beam was demonstrated, showing that – not only the ASE prepulse of nanosecond duration – but the so called coherent pedestal of CPA schemes can also be removed. The observed efficiency of 25% was lower than the 40% one obtained for UV lasers. The reason of the limited efficiency and discussions on the possible improvements will be given.

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Non-Thermal Structural Transformation of Diamond Driven by X-Rays

Phil Heimann[1], Nicholas J. Hartley[2], Ichiro Inoue[3], Victor Tkachenko[4], Andre Antoine[5], Fabien Dorchies[6], Roger Falcone[7], Jerome Gaudin[6], Hauke Höppner[8], Yuichi Inubushi[9], Konrad J. Kapcia[10], Hae Ja Lee[1], Vladimir Lipp[10], Paloma Martinez[6], Nikita Medvedev[11], Franz Tavella[1], Sven Toleikis[12], Makina Yabashi[3], Toshinori Yabuuchi[3], Jumpei Yamada[3], Beata Ziaja-Motyka[13]

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Intense x-ray pulses can cause the non-thermal structural transformation of diamond. At the SACLA XFEL facility, pump x-ray pulses triggered this phase transition, and probe x-ray pulses produced diffraction patterns. Time delays were observed from 0 to 250 fs, and the x-ray dose varied from 0.9 to 8.0 eV/atom. The intensity of the (111), (220) and (311) diffraction peaks decreased with time indicating a disordering of the crystal lattice. From a Debye-Waller analysis, the rms atomic displacements perpendicular to the (111) planes were observed to be significantly larger than those perpendicular to the (220) or (311) planes. At a long time delay of 33 ms, graphite (002) diffraction indicates that graphitization did occur above a threshold dose of 1.2 eV/atom. These experimental results are in qualitative agreement with XTANT+ simulations using a hybrid model based on density functional tight-binding molecular dynamics [1].

[1] Heimann et al., Non-thermal structural transformation of diamond driven by x-rays, *Structural Dynamics* 10, 054502 (2023), `https://doi.org/10.1063%2F4.0000193`.

Temperature and Structure Measurements of Heavy-Ion-Heated Diamond Using in Situ X-Ray Diagnostics

Julian Lütgert[1], Philipp Hesselbach, Maximilian Schörner[2], Vincent Bagnoud[3], Roman Belikov[4], Philipp Drechsel[5], Benjamin Heuser[6], Oliver Humphries[7], Peter Katrik[3], Björn Lindqvist[8], Chongbing Qu[2], Ronald Redmer[2], David Riley[9], Gabriel Schaumann[10], Samuel Schumacher[2], Andreas Tauschwitz[3], Dmitry Varentsov[3], Karin Weyrich[3], Xiao Yu[3], Bernhard Zielbauer[3], Zsuzsanna Slattery-Major[3], Paul Neumayer[3], Dominik Kraus[11]

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[11]HZDR

Graphitization of diamond can be induced by heating it to temperatures below 2000K in an evacuated oven over minutes, or within 100s of femtoseconds if sufficient energy is deposited locally, e.g. by an XFEL beam. However, despite the bombardment of diamond by fast ions being a typical scenario at accelerator facilities like GSI or FAIR – where it is used as a detector material – intermediate times as well as the different mechanism of ions interacting with the material's lattice directly, lack understanding.

We present *in situ* measurements of spectrally resolved x-ray scattering and spatially resolved x-ray diffraction from monocrystalline diamond performed at the HHT (high-energy, high-temperature) experimental area at GSI. Combining the two x-ray diagnostics, we determine the sample's heating dynamics and its microscopic and macroscopic structural integrity over a timespan of several microseconds. Connecting the ratio of elastic to inelastic scattering with state-of-the-art density functional theory molecular dynamics simulations allows for inferring average bulk temperatures around 1300K in agreement with predictions from stopping-power-calculations. The simultaneous diffraction measurements show no hints for a volumetric graphitization of the material but indicate the onset of fracture in the sample.

We will discuss improvements to the experimental setup to increase the heating of the sample and the measurements' signal-to-noise ratio for a follow-up campaign scheduled in summer 2024, further exploring our temperature diagnostic and investigating the graphitization of ion-heated diamond.

Electron-Phonon Coupling in Warm Dense Metals

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In metallic samples illuminated with ultrashort laser pulses, the electrons are rapidly heated to temperatures ranging in the tens of thousands of Kelvin within a timescale that is comparable to the duration of the pulse, while the ions remain at a much lower temperature. The process of equilibration between the two temperatures occurs over several picoseconds and is determined by the electron-ion coupling factor. In this study, we have employed methods based on Density-Functional Theory and Density-Functional Perturbation Theory to investigate the thermal relaxation of warm dense gold and molybdenum and to calculate the electron-ion coupling factor for extreme values of the electronic temperature. Our approach involves revisiting the formulations presented in existing literature and improving the accuracy of the calculations by eliminating most of the approximations used in other studies. Our results provide valuable insights into the non-equilibrium dynamics of metals in the warm dense matter regime.

Grating-Based Phase-Contrast Imaging of Laser-Driven Shock-Waves

Stephan Schreiner[1], Leonard Maximilian Wegert[2], Paul Neumayer[2], Bernhard Zielbauer[2], Artem Martynenko[2], Constantin Rauch[1], Markus Schneider[1]

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Single-shot x-ray phase-contrast imaging was used at the PHELIX and LULI laser to capture sharp images of propagating plasma shock fronts in dense matter. With a two grating Talbot interferometer we were able to obtain a standard radiography, a differential phase-contrast and a Dark-field image of the shocked target. FLASH simulations were performed and superimposed with the data from the experiment. Simulation and experiment show good agreement. The performance of the interferometer is evaluated, and the main contributor to image noise are identified and discussed. The obtained images show that Talbot interferometry is a powerful diagnostic for High-energy-density science with the ability of retrieving the projected electron density of the imaged sample.

Ab Initio Approach to Static and Dynamic Properties of Partially Ionized Plasmas and Strongly Coupled Uniform Liquids of Charged Fermions

Alexey Filinov[1], Michael Bonitz[2], Igor M. Tkachenko[3]

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With the upcoming new experimental colliding planar shocks platform, in particular, at the NIF and the FAIR facility at GSI Darmstadt, high precision thermodynamic data for highly compressed matter will be needed. This poses new challenges to theory and simulations. However, even for such relatively simple elements like hydrogen, first principle equation of state (EOS) data free of systematic errors,

are still absent.

In this content we have developed a novel first-principle fermionic path integral Monte Carlo (MC) approach for hydrogen (deuterium) plasma[1] which is free of the fixed-node approximation[2]. The deviations in the thermodynamic data provided by both quantum MC methods are generally found to be small, but for the lowest temperature isotherm, $T = 15,640$K, they amount to several percent.

The revised EOS have been constructed for temperatures in the range $15,000$K $\leq T \leq 400,000$K and densities $7 \cdot 10^{-7}$g/cm^3 $\leq \rho_H \leq 0.085$ g/cm^3 ($1.4 \cdot 10^{-6}$g/cm^3 $\leq \rho_D \leq 0.17$ g/cm^3). This provides new opportunities to improve alternative simulation methods as well as chemical models for the challenging conditions of warm dense matter.

As a next step we plan to analyze the dynamic properties of plasmas based on a novel non-perturbative self-consistent method of moments. We have recently successfully applied this approach to analyze the eigenmodes' explicit temperature/density dependence both in uniform electron fluids and in 3He, where for strong coupling we predicted a bimodal structure of the excitation spectrum with a lower-energy mode possessing a well pronounced roton-like feature[3].

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Ultrafast Melting of Copper: Experiment and Theory

Baerbel Rethfeld[1]

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Friday (February 2nd)

Start	Duration	Speaker	Title
Session 12: Diagnostics and Targets (Chair: T. Kühl)			
08:30	0:20	QI, Wei	High Efficient and High Directionality Neutron Source Driven by Short-pulse Laser
08:50	0:20	CHENG, Rui	Progress of the Preliminary HEDP Research Based on HIRFL
09:10	0:20	YANG, Jie	Electron-Ion Three-Body Recombination in Strongly Coupled Ultracold Plasma
09:30	0:20	RACZKA, Piotr	Target Charging and Electromagnetic Pulse Emission in Laser-Driven Ion Acceleration
09:50	**00:30**	**Coffee break**	
Session 13: Implosions and Astrophysical Plasmas (Chair: P. Neumayer)			
10:20	0:20	BARRETT, Sean	First Light's Multi-Physics Codes for ICF
10:40	0:20	YADAV, Naveen	Designing Ion Accelerators Using the High-Power Laser Nano-rod Interaction: A Numerical Investigation
11:00	0:20	ALLISON, James	EoS Uncertainty Quantification Applied to First Light Fusion Amplifier Design
11:20	0:20	PAUW, Viktoria	Advanced Data Analysis on Laser-Plasma Interaction Simulations with Particle-In-Cell Codes
11:40	0:20	PANDEY, Rishav	Detector and Physics Simulation Using Heavy Ion Collisions at NICA-SPD
12:00			**Conclusion and End of Workshop**

High Efficient and High Directionality Neutron Source Driven by Short-Pulse Laser

Qi Wei[1]

[1]Laser Fusion Research Center

The neutron sources driven by ultra-intense ultra-short lasers have many advantages, such as small source size, short duration, high fluency etc. The studies of laser-driven neutron sources (LDNS) thus have attracted much interest and has shown unique potential both for innovative investigations and for applicative purposes in the past two decades.
Experiments of LDNS has been carried out in the XGIII laser facility at the Laser Fusion Research Center of the Chinese Academy of Physics, and the yield of 2×10^9 n/sr was reached by using a 147 J picosecond laser with intensity of 6×10^{19} W/cm^2. Compare with former experiments, the yield is increased about 10 times by using advanced TNSA target and more efficient convertor. Another important experiment was performed on the SILEX-II Petawatt laser facility. Laser accelerated lithium ions hit the CD_2 foil and highly directional neutron beam was generated with the ratio of yield between 0° and 90° greater than 10. This kind of neutron source has great advantage in neutron application such as neutron spectroscopy and radiography because the shield of neutrons on the sides can be greatly reduced.

Progress of the Preliminary HEDP Research Based on HIRFL

RUI CHENG[1], *Zhao WANG*[2], *Zexian ZHOU*[2], *Yu LEI*[2], *Yanhong Chen*[2], *Jie Yang*[2]

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[2]IMP

Heavy ion beam driven High-Energy-Density-Physics (HEDP) is one of the important research topics at the future facility of HIAF, and the first beam experiment is planned happening in 2025-2026. In order to improve our understanding about the energy deposition of ions in plasmas and develop the diagnoses to determine the dynamic process of HEDM, some new plasma targets and a multi-channel X-ray FSSR are developed respectively at IMP. Moreover, a preliminary experiment is carried out based on the HIRFL and a new beam-line update plan has been made.
In this workshop we will introduce the new progress around Beam-driven HEDP based on the HIRFL.

Electron-Ion Three-Body Recombination in Strongly Coupled Ultracold Plasma

Fang Feng[1], *Changjie Luo*[1], *RUI CHENG*[2], *Xinwen MA*[1], *Jie Yang*[3]

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[2]INSTITUTE OF MODERN PHYSICS, CHINESE ACADEMY OF SCIENCES

[3]Institute of Modern Physics (IMP)(IMP)

Ultracold plasmas are ideal carriers for experimental studies of strong coupling properties, as the coupling strength of electrons (or ions) can be selected over a wide range by changing the initial temperature. We presented the measurement results of the relationship between the number of Rydberg atoms and the number of ions in ultracold plasma, and found that the three-body recombination process changes significantly with the initial electron coupling strength. When the initial electron temperature is high (weakly coupled), the number of Rydberg atoms is proportional to the third power of the number of ions, which is a direct proof of the three-body recombination process. When the initial electron temperature is low (strongly coupled), the scaling law of Rydberg atoms with ions is around 1.7, which is consistent with theoretical predictions, indicating that the electron process is strongly influenced by the strong coupling conditions. In addition, the self-similar diffusion model under strong coupling conditions is also discussed.

Target Charging and Electromagnetic Pulse Emission in Laser-Driven Ion Acceleration

Piotr Rączka[1], Marcin Rosiński[1], Michał Kustosz[1], Przemysław Tchórz[1], Agnieszka Zaraś-Szydłowska[1], Maciej Szymański[1], Oleh Byrka[2], Anna Marchenko[3]

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[3]Institute of Plasma Physics and Laser Microfusion; Institute of Plasma Physics, Kharkov Institute of Plasma and Technology

One of the side effects of high-intensity laser-target interactions under conditions typical for laser-induced proton acceleration is a strong emission of electromagnetic pulses (EMP) in the MHz to multi-GHz frequency range, as was recently reviewed in [1]. Such pulses strongly interfere with the electronics used to collect data and to manipulate targets and hence pose a serious threat to safe and reliable operation of the high energy and high intensity laser facilities. For this reason studies aimed at EMP characterization and the development of the EMP mitigation methods are of utmost importance. Physically the EMP emission is related to the the well-known phenomenon of creation and propagation of hot electron bunches, which results in particular in target charging [2]–[4] and generation of strong neutralization currents, but a comprehensive quantitative predictive description is still a challenge. In our contribution we report on experimental studies of EMP generation and mitigation performed on the 0.4 J/40 fs laser at IPPLM and other high intensity laser facilities in Europe, as well as the numerical studies. In particular, we discuss the so-called “birdhouse” EMP mitigation concept [5], [6] in which the target foil is placed inside a conductive box that absorbes some part of the escaping electrons and the electromagnetic signal emitted directly from the target. We also explore methods to make constructive use of the target charging effect.

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First Light’s Multi-Physics Codes for ICF

Sean Barrett[1], Nicolas Niasse[1], David Chapman[1], Nathan Joiner[1], Nicholas Hawker[1]

[1]First Light Fusion

First Light Fusion relies on a powerful predictive capability to quickly and cheaply iterate on our target designs *in-silico*. We have developed two codes in-house for this purpose. The first, Hytrac, is a front-tracking 2D radiation hydrodynamics code, with a high fidelity interface treatment, adaptive mesh refinement, and high-order solvers for compressible Eulerian hydrodynamics. The second, B2, is an Eulerian 3D magneto-radiation hydrodynamics code. Originally developed for simulating electromagnetically accelerated projectiles, it now has a full suite of physics operators for ICF, including a model of the transport of charged D-T fusion products. The accuracy of both codes is continuously verified with a comprehensive suite of tests, in which we compare to analytic solutions and the output of other codes. In this talk I will summarise our codes’ features and verification strategy, describe how we implemented radiation transport in both codes, and how we developed our prototype charged particle transport capability.

Designing Ion Accelerators Using the High-Power Laser Nano-Rod Interaction: A Numerical Investigation

Naveen Yadav[1], Hartmut Ruhl[2], Marius Schollmeier[1], Georg Korn[1]

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[2]LMU

At Marvel Fusion GmbH, we are pursuing a novel ICF concept utilising ultra-short laser pulses interacting with structured materials such as nano-rod arrays. The highly efficient conversion of laser energy to directed ionic motion resulting from these interactions has potential applications for inertial confinement fusion. When employed in the capacity of high-ionic current nano-accelerators, this interaction can be used for volumetric ignition of specifically designed fuel capsules. While we have an ongoing experimental campaign to benchmark these interactions, in this talk, we focus on their numerical investigation. We have simulated the laser-plasma interaction between a femtosecond laser pulse modelled as a plane wave and a nano-rod array modelled using periodic boundary conditions. The interaction results in ionic explosions or, in other words, creates a nano ion accelerator. We systematically explore the effects of varying laser intensity, pulse width, and wavelength using nano-rods with different radii on the ionic energy spectra and the efficiency of laser-to-particle energy conversion in these nano-accelerators. The two critical features in nano-accelerators that make them useful for fusion are (a) efficient coupling of laser energy to matter on timescales of 100 femto seconds and (b) the directed ionic currents whose energy and momentum content can be controlled. In the future, we intend to use these numerical nano-accelerator models as building blocks for designing nano-targets.

EoS Uncertainty Quantification Applied to First Light Fusion Amplifier Design

James Allison[1], Damilola Adekanye[1], Victor Beltran-Martinez[2], Thomas Edwards[1], James Pecover[2], Dave Chapman[1], Nathan Joiner[1], Nicholas Hawker[1], Rafel Bordas[1]

[1]First Light Fusion Ltd
[2]First Light Fusion Ltd.

Equation of State (EoS) models are a significant source of uncertainty in the design of high-energy-density physics experiments. This is principally due to a lack of wide-ranging high-fidelity data across the ρ-T plane, for example, from experiments or *ab initio* simulations. Furthermore, global analytical models of the EoS do not include important physics at the atomic scale. The significant challenge in quantifying and propagating these uncertainties is the requirement to maintain both thermodynamic consistency between state variables and stability conditions required for robust hydrodynamic modelling.

One could simply vary the parameters of the EoS-generating model, but this would fail to capture important uncertainties due to choices of functional form. Therefore, at First Light Fusion (FLF) we have chosen to adopt a non-parametric statistical model using physics-informed Gaussian Processes (GPs). Guided by the deviations observed between our global QEOS models and literature experimental Hugoniot data, we have constructed a GP model that defines the EoS probability distribution over the input (ρ, T) space. Crucially, this approach allows us to vary the EoS uncertainty across (ρ, T) space conditioned on the available of data. EoS tables are then sampled from this distribution and used to drive an ensemble of hydrodynamic simulations for uncertainty quantification and sensitivity analysis of our experimental designs. We have implemented this as a physics-informed framework in 'GPyTorch', a modern GPU-enabled 'Python'-based GP library, which can be used with any tabulated EoS for hydrodynamic simulations.

In this talk we present a case study of this method applied to the FLF Endor amplifier design; a target for amplification of the shock pressure generated by uniaxial drive. We will show results from a full sensitivity analysis of the Endor amplifier to EoS uncertainty for each material. The framework we have developed allows for further refinement of the uncertainty model with the inclusion of information from new data.

Advanced Data Analysis on Laser-Plasma Interaction Simulations With Particle-in-Cell Codes

Viktoria Pauw[1]

[1]Ludwig Maximilians Universität

We report on an in-depth evaluation of large outputs of particle in cell simulations (carried out with the PSC, by Prof. Ruhl et al, LMU). Object of the simulations are micro-spheres irradiated by ultra-short relativistically strong laser pulses modeling experiments of Jörg Schreibers group at CALA (`https://cala-laser.de/`) and Texas Petawatt Laser (`https://texaspetawatt.ph.utexas.edu/`). The atoms in these spheres are ionized completely by the electric fields of the pulse and act as so-called mass limited targets (MLT) for acceleration of ions (predominantly protons) to energies up to hundreds of MeV. The ensuing plasma dynamics inside the target are highly complex and display distinctly different patterns depending on the parameters of the target and laser pulse.
In the project, target size, density and composition as well as laser pulse properties were varied and dozens simulation runs with different parameters were executed. Scanning densities from 2 n_c to solid densities (336 n_c), we observe that in addition to the ion acceleration driven by heating and ponderomotive electron removal (TNSA, Coulomb explosion), an RPA driven compression effect can significantly contribute to the acceleration, when the target density is in the relativistically transparent range. This can be observed in depth by evaluating electrons and protons both collectively and as single trajectories.
We explore different techniques for the time consuming post-processing and management of the raw simulation outputs and intermediate processed data and evaluate alternative techniques for data analysis including special database systems tailored for use in scientific data processing.

Detector and Physics Simulation Using Heavy Ion Collisions at NICA-SPD

Igor Denisenko[1], *Rishav Pandey*[2]

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The space-time picture of hadron formation in high-energy collisions with nuclear targets is still poorly known. The tests of hadron formation was suggested for the first stage of SPD running. They will require measuring charged pion and proton spectra with the precision better than 10%. A research has been carried out to check feasibility of such studies at SPD. In this work, $^{12}C - ^{12}C$ and $^{40}Ca - ^{40}Ca$ heavy ion collisions at center of mass energy of 11 GeV/nucleon were simulated using the SMASH event generator. Firstly, the generator-level events were studied. The distribution of track multiplicities and momentum distributions of different types of charged particles were obtained. Secondly, the generated events passed through the full reconstruction using the SpdRoot framework. At this stage particles were identified using dE/dx measurement and time-of-flight information. It allowed us to estimate charge track multiplicities in the tracking system and purities of charge particles spectra. The results on multiplicity are important to estimate occupancies in the tracking system, while the results on the pion and proton momentum spectra show that particle identification should be acceptable for validation of hadron formation models. This is the first study of moderate ion collisions for the SPD Collaboration.

Keywords: Hadron formation effects, Heavy ion collision, SMASH, NICA-SPD, Rapidity, Charged track multiplicity, Particle physics event generator.

Poster Session (Wednesday, 17:00-18:30)

1	BOLLER, Pascal	Numerical Optimization of the Target Thickness for Experiments in the Relativistic Transparency Regime at PHELIX
2	FÖLDES, Istvan	Hot Electrons from Laser-Plasma Interactions with the ABC Laser System
3	WANG, Xing	Ion-Induced Alignment and Magnetic Sub-State Ionization in L3-Subshell
4	NEFF, Stephan	Experimental Facilities for High-Energy Density and Warm Dense Matter Experiments at FAIR
5	MISHCHENKO, Mikhail	Ionization and Relaxation Dynamics in Laser Plasmas Using X-Ray Free Electron Lasers
6	WASSER, Florian	Investigation of Laser Plasma Instabilities Driven by 527 nm Laser Pulses Relevant for Direct Drive Inertial Confinement Fusion
7	XU, Zhongfeng	Experimental Determination of Atomic Alignment of 42Mo, 48Cd and 49In with Differential X-Ray Intensity Ratios by 100-250 keV Proton Impact
8	VÁZQUEZ-MOYANO, José	Analysis of 4+ Carbon Projectiles Energy Loss Passing Through Carbon Plasma Experiment within LIGHT Project at GSI
9	BESPALOV, Dmitrii	Target Design for High-Pressure Temperature Matter Using Inelastic X-Ray Scattering at the HED Instrument at the European XFEL
10	FRASER, Adam	SpK - A Fast Atomic Physics Code for Generating Tabulated EoS and Opacity Data for Use in HEDP Simulations
11	DAUERER, Leon	Laser Pumping with LEDs
12	BARRIGA-CARRASCO, Manuel	Theoretical Methods and Simulations of the Magnetized Plasmas Stopping Power
13	ZHAO, Yongtao	Activities on High Energy Density Physics at Xi'an Jiaotong University
14	GAO, Yifang	Measurements and Determinations for the Charge Quantity of Brilliant Electron Beams Generated Through Laser-NCD Plasma Interaction
15	WEGERT, Leonard	Observing the Interaction of Shocks with Interstellar Clouds in the Lab
16	RIPS, Johannes	Exploring the Phase Diagram and Diamond Formation of Double Shocked PET Using In Situ X-Ray Diffraction
17	BRÖNNER, Matthias	Objective Functions in Isochoric Design Studies for Proton Fast Ignition
18	ZOBEL, Nick	Alternative Hydrogen Storage Concepts

Numerical Optimization of the Target Thickness for Experiments in the Relativistic Transparency Regime at PHELIX

Pascal Boller[1], Johannes Hornung[1], Vincent Bagnoud[1]

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Laser-driven ion acceleration has been studied extensively for the last 20 years and the results obtained by many laboratories worldwide demonstrate its many advantages in contrast to conventional accelerators like high brightness, ultrashort bunch length, and low beam emittance [1, 2]. In addition, the footprint of a laser-driven ion source is more compact, which has an impact on the facility's cost, and a wide range of potential applications in healthcare, industry, and nuclear physics.
To exploit this potential, a lot of effort must be invested in laser development, as well as in the understanding and optimization of the acceleration process. Current investigations on laser-driven acceleration deal with solid targets that become transparent during the interaction with the laser, reaching conditions where the laser interacts volumetrically with the target electrons. Such conditions can be found only at extremely high intensities when relativistic effects must be additionally accounted for. This process is extremely transient and takes place at time scales similar to the laser pulse duration itself, which makes them hard to control. In addition, the target pre-heating due to the real laser profile and rising slope needs to be taken into account to get the right picture of the process numerically.
In this work, I present a numerical study dealing with a parameter scan in the target thickness for the PHELIX facility and claim the optimum target thickness in the relativistic transparent regime at this facility. The hydrodynamic code Flash simulates the effect of the 100-ps-long rising slope of the laser on the initially-solid target. The results provide the input parameters of the PIC code, Epoch-2D. This parameter scan provides insight into the optimal target thickness range of the relativistic transparency at the PHELIX facility.

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Hot Electrons From Laser-Plasma Interactions With the ABC Laser System

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Shock ignition [1] is an attractive method to realize inertial fusion energy (IFE) production. In this case the fusion capsule is compressed first slowly, then a short pulse of 1016 W/cm2 will ignite the fusion fuel. In the case of such intensities nonlinear laser-plasma effects may gain importance. It was shown that in case of a dominant Raman scattering the fast electrons of less than 100 keV may even help the ignition process. However, the fast electrons from two-plasmon decay may have energies of well above 100 keV, taking away the energy and preventing ignition [2]. Therefore it is essential to determine fast electron temperature. A conical von Hamos spectrometer was recently developed [3] to investigate simultaneously the Ni and Cu K� radiation, thus giving basis of accurate temperature measurement by measuring the ratio of hot electron generated K� radiation emitted from different depths of the target. 1D MULTI simulations were carried out to estimate the temperature and density of plasmas. This allowed us to estimate the thickness of the ablator which was Al in our case. Also the estimated plasma profiles allow the estimation of the convective thresholds of nonlinear interactions. Preliminary experiments were carried out with Al-Cu-Al-Ni targets at the ABC laser facility (1054 nm laser beam of 30 J energy with 3 ns duration) of ENEA which provides hot electrons of 100 keV energy.
The technical asiistance of Leonardo Manzoni is acknowledged this way. This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. The involved teams have operated within the framework of the Enabling Research Project: ENR-IFE.01.CEA "Advancing shock ignition for direct-drive inertial fusion".
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Ion-Induced Alignment and Magnetic Sub-State Ionization in L3-Subshell

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Many-body systems with excess internal energy relax towards states of lower energy by rearrangement of molecular, atomic or nuclear structure. Excitation of a strongly bound electron from an atomic inner shell is followed by an ultrafast rearrangement of the electronic system, resulting in a disappearance of the inner-shell vacancy. As is well known, atomic inner-shell spectroscopy can provide various information about the collision system.

Alignment property of electron vacancies produced by protons bombardment are investigated in low energy region from 100 keV to 250 keV. Characteristic L X-ray spectra are measured for $_{42}$Mo, $_{48}$Cd and $_{49}$In targets respectively at emission angles from 115° to 155°. Angular dependence of differential intensity ratios $L_\alpha/L_{\beta1}$ and $L_{\beta2}/L_{\beta1}$ has been studied as a function of the second-order Legendre polynomial $P_2(\cos\theta)$. This served to reduce the experimental uncertainties. Then the anisotropy parameter β is converted to alignment parameter $\mathscr{A}_{20}$ by considering CK correction coefficient and anisotropy coefficient. The measured results are compared with other measurements, as well as calculations by semiclassical approximation, and good agreement is found in general. Small discrepancy is attributed to the atomic parameters employed only for single ionization.

Furthermore, collision-induced atomic alignment of silver by 10–50 keV electrons impact is also investigated to explore the influence of CK transition effect. The incident energy range is 10-50 keV, i.e., (3$\sim$15)E_{L_3}, where E_{L_3}(=3.351 keV) is the binding energy of electrons in the L_3-subshell. It is found that the influence of CK transition is significant for large alignment parameters. The experimental results are compared to theoretical predictions within the framework of Plane Wave Born Approximation (PWBA) and reasonable agreement is found in the energy range studied in the present work. Simultaneously, good scaling property of atomic alignment is demonstrated when we consider also previous experimental results. This measurement extends the scaled velocity $V(= v_p/v_t)$ to a range of 1$\sim$4 for medium-Z_t targets, and the results of atomic alignment can provide an important and fundamental testing ground for ionization models.

Experimental Facilities for High-Energy Density and Warm Dense Matter Experiments at FAIR

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At the site of the Gesellschaft fuer Schwerionenforschung (GSI) in Darmstadt, the Facility for Antiproton and Ion Research (FAIR) is currently under construction. FAIR will offer unique high-intensity heavy ion beams and high-intensity proton beams for experiments covering many fields of research, including the study of high-energy density samples and the study of warm dense matter.
The research in this field is coordinated by the High Energy Density Science at FAIR (HED@FAIR) collaboration, which will focus on four main fields of study: (1) The study of the properties of materials driven to extreme conditions of pressure and temperature; (2) The study of shocked matter and of equations-of-state; (3) The study of basic properties of strongly-coupled plasma and warm dense matter; and (4) Nuclear photonics, including the excitation of nuclear processes in plasmas and laser-driven particle acceleration and neutron production.
The SIS-100 heavy ion synchrotron at FAIR will provide heavy ion beams with up to 5*10^{11} U^{28+} ions with 2 AGeV in a 50 ns bunch for plasma physics experiments where they will be used either to isochorically heat macroscopic samples to eV temperatures or to indirectly compress them to megabar pressures. In addition, SIS-100 will also high-energy protons (up to 10 GeV with up to 2.5*10^{13} protons per bunch) which will be used for a proton microscope.
Due to the new timeline of the FAIR project, the HED@FAIR experiments have been delayed. Until the setup at FAIR becomes available, HED experiments are therefore focusing on using the facilities at GSI. In my presentation I will give an overview of the experimental facilities for HED experiments at FAIR and at GSI in Phase 0 and give a status update of the current situation.

Ionization and Relaxation Dynamics in Laser Plasmas Using X-Ray Free Electron Lasers

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In the interaction of ultra-short relativistic laser pulses with solid targets, the temperature, density, and other key plasma parameters are determined by the dynamics of heating and ionization, as well as relaxation and recombination. We have demostrated platform, which allows to use time-depandant resonant probing of radiative K-transitions in relativistic plasmas as a method for the study of spatial and temporal ionization relaxation dynamics.

Experimentally obtained data on the dynamics of ionization and relaxation could significantly improve particle-in-cell simulations, and avoid errors in estimating reaction rates and overestimating the degree of ionization. [1,2]

The unique capabilities of the HED instrument at the European XFEL allow the creation of a unique platform where intense X-ray pulses are synchronized with an accuracy of 20-30 fs with the sub-petawatt class ReLaX laser.[3] Thanks to this, we were able to measure the lifetime of the oxygen-like ionization state for copper plasma obtained from flat foil irradiated by ultra-relativistic laser pulses, and also to demonstrate the effectiveness of resonant X-ray pumping in determining the spatial and temporal dynamics of ionization in laser plasma.

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Investigation of Laser Plasma Instabilities Driven by 527 Nm Laser Pulses Relevant for Direct Drive Inertial Confinement Fusion

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The demonstration of ignition and net energy gain at the National Ignition Facility has paved the way for inertial fusion energy. The recently established company Focused Energy has presented a concept to address the demands for an inertial fusion power plant, in particular a fusion gain that is sufficient to compensate for the electrical power consumption of the plant, stable long-term operation and cost efficiency. One aspect is the use of laser light with a wavelength of 527 nm instead of 351 nm to compress the fusion pellets, which has considerable benefits for a fusion power plant including lower facility costs and higher optics damage thresholds.
One of the scientific challenges especially for 527 nm light, are laser plasma instabilities (LPI) such as stimulated Brillouin scattering (SBS), stimulated Raman scattering (SRS), two-plasmon-decay (TPD) and cross-beam energy transfer (CBET) since they reduce the laser-energy coupling and may cause hot electron preheat of the fuel.
In this contribution we report on an extensive study of SBS and SRS using the frequency doubled kilojoule high repetition rate L4n laser at the Extreme Light Infrastructure (ELI) – Beamlines for plasma parameters entering a regime that is relevant for direct drive inertial confinement fusion. We scanned the laser intensity range of 0.5×10^{13}–1.1×10^{15} Wcm^{-2} with more than 1300 shots and measured the onset and growth of the instabilities with a high confidence level. This dataset will be used as a benchmark for extensive studies of LPI mitigation techniques.

Experimental Determination of Atomic Alignment of 42Mo, 48Cd and 49In With Differential X-Ray Intensity Ratios by 100-250 keV Proton Impact

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This work aims to study the alignment property with protons in low energy region from 100 keV o 250 keV. It is of important significance in atomic processes in plasma and elementary analysis technique such as particle induced X-ray emission method. The alignment degree A20 of 42Mo, 48Cd and 49In ions after L3 subshell ionization by proton impact has been investigated experimentally in low energy regime 100-250 keV. The typical L X-ray spectra are measured for each. The typical L X-ray spectra are measured for each target at emission angles from 115° to 155°. Angular dependence of differential intensity ratios Lα/Lβ1 and Lβ2/Lβ1 are studied as a function of the second-order Legendre polynomial P2(cosθ). It demonstrates that Lα and Lβ2 lines exhibit anisotropic emission spatially.

The anisotropy parameter is converted to alignment degree by considering the Coster-Kronig (CK) correction coefficient and anisotropy coefficient. The investigation offers experimental evidence to the existence of alignment for atomic ionization in proton-impact process. The results are discussed with theoretical prediction within the framework of the semiclassical theory of inner shell ionization, and good agreement is found in general. Small discrepancy around the inflection point of alignment degree is attributed to the atomic parameters employed only for single ionization in CK correction coefficient.

Analysis of 4+ Carbon Projectiles Energy Loss Passing Through Carbon Plasma Experiment Within LIGHT Project at GSI

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In this work, we analyze the energy loss of 4^+ carbon projectiles at an energy of 0.6 MeV/u as they pass through a carbon plasma of the experiment to be carried out at GSI within the LIGHT (Laser Ion Generation, Handing and Transport) project. In this experiment, the aim is to measure the energy loss of carbon ions as they pass through a laser-generated carbon plasma. LIGHT provides ion pulse lengths of around 1 ns lower than the 5.5 ns of previous experiments, which improves the temporal uncertainty when measuring the energy loss.

The plasma will be generated by using two frequency-doubled laser beams from the ns-Laser (nhelix) with a configuration of E = 2 x 30 J, τ = 7 ns, λ = 532 mm and I = 4.6E11 W/cm^2 incident on both sides of the 105 μg/cm^2 thin carbon foil. On the other hand, a carbon ion beam of 1.23 ns FWHM and 8.4 mm focal spot will be generated using the PHELIX laser with a configuration of E = 30 - 40 J, τ = 650 fs, λ = 1053 nm, d_t = 3. 5 μm and I > 1E19 W/cm^2. Based on these experimental conditions, plasma simulations will be carried out using the MULTI-IFE [1] hydrodynamic simulation code, which will provide us with the theoretical data of the plasma state to estimate its stopping power and therefore find the energy loss of the ion beam passing through it.

The estimation of the energy loss of an ionic projectile in a plasma has a quadratic dependence on the charge state of the projectile, therefore a correct estimation of the instantaneous charge state of the projectile is of great importance. For this purpose, we will use our successful model that uses rate equations based cross sections that describe all the processes of losses and electronic captures that the projectile undergoes in its interaction with the plasma, which we have already defined in [2]. In addition to this charge state model, we will use for comparison the semiempirical models of Kreussler [3] and Guskov [4]. For the calculation of the stopping power due to plasma free electrons we will use the T-Matrix model as described in [2], while for the calculation of the stopping power due to plasma bound electrons, we will use PLASTOP [5]. Finally, the interaction of the projectile with the plasma will be treated in detail, since the plasma parameters are not constant along the projectile trajectory, causing instantaneous variations in the charge state of the projectile, which directly affects the stopping power and the resulting energy loss. By considering the changing stopping power experienced by the projectile, the energy of the projectile is updated, which in turn affects all the above parameters.

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Target Design for High-Pressure Temperature Matter Using Inelastic X-Ray Scattering at the HED Instrument at the European XFEL

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The investigation of Warm dense matter (WDM) is of high significance in the fields of planetary science, astrophysics, and material science. Traditional methodologies, such as ideal plasma statistics and solid-state theory, exhibit limitations in WDM research. This work details the application of inelastic x-ray scattering at the High Energy Density (HED) instrument of the European X-ray Free Electron Laser (XFEL), focusing on high spectral resolution studies of WDM. Operational since 2019 [1], the HED instrument is equipped with a monochromator of 45 meV resolution, suitable for the study of materials in extreme conditions [2], specifically for the measurement of phonon and ion-acoustic wave dispersions.

This study introduces an advanced target design for these experiments, developed through hydrodynamic simulations of aluminum targets subjected to ns-laser irradiation for high-pressure WDM investigations. The selection of aluminum is based on its material properties and the objective of corroborating existing data. The resulting target design has enhanced the WDM research capabilities of the HED instrument, as evidenced by initial tests.

Additionally, at the SACLA facility, we conducted experiments using aluminum targets with silicon ablators. These experiments focused on imaging these targets to explore their behavior under high-pressure conditions, a key aspect in the study of Warm Dense Matter. The initial results from SACLA are promising, suggesting advancements in our understanding of WDM's response to high-pressure environments.

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SpK - A Fast Atomic Physics Code for Generating Tabulated EoS and Opacity Data for Use in HEDP Simulations

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SpK is a fast atomic physics code developed to produce tabulated self-consistent Equation of State (EoS) and opacity data for use in High-Energy-Density Physics (HEDP) simulations. Shell structure is captured by solving the Saha equation, with energy levels obtained from the NIST database or the Screened Hydrogenic Model with ℓ-splitting [1], allowing distributions of ionisation states and level populations to be obtained for a wide range of densities and temperatures. Extending to the TF model in strongly coupled conditions and using semi-empirical bonding corrections to reproduce the correct conditions at solid density and atmospheric pressure, a full capability has been developed to model the full transition from a solid material into the plasma state.

Following on from our recent paper on the opacity capabilities within SpK [2], this work focuses on the developments made to calculate EoS data, including some examples of validation and benchmarking of its predictions. Following this, the importance of accurate material properties data is demonstrated in the integrated modelling of conically convergent shock tube experiments [3], with SpK providing the best plasma EoS for agreement with the validation data.

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Laser Pumping With LEDs

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Laser Pumping with LEDs
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Right now, high intensity and high-energy laser systems are pumped by flash lamps or laser diodes. The flash lamps have a very large emission bandwidth (>2000 nm), which makes them inefficient and limits the repetition rate of the laser, while the narrow-bandwidth laser diodes (2-6 nm) remain very expensive (30-50$/W). These characteristics are problematic for the application for laser driven fusion, because a commercially-functioning power plant would require high repetition rates, high efficiency and low costs. In this contribution, we focus on the question if LEDs can serve as a good compromise between flash lamps and laser diodes.
In the past years, LEDs have developed tremendously as well as in cost as in performance. For example, the price for light (per kilolumen) dropped by a factor of 15 over the course of the last decade, driven by the lighting industry. In addition, the performance/efficiency increased over time. They have an acceptable bandwidth (20-60 nm), so there is significantly less unnecessary energy deposited in the amplifier material compared to flash lamps. In comparison to the laser diodes, they are a lot cheaper (20-40 ct/W). However, LEDs still exhibit low emission power densities, which has been regarded as a challenge for laser applications. A work around is the possibility to overdrive LEDs in pulsed operation mode, which has received little attention so far.
This contribution focusses on the measurements of the possible power and efficiencies that can be obtained with the pulsed mode of LEDs. The LEDs, which we studied, are the BestSMD_2835FIRC81L42I1A LEDs which emit at 810 nm, making them suitable for pumping Nd:Glass. The lifetime of the Nd:Glass states are in the magnitude of 250 µs, so we focused also on pulse length up to 500 µs. We investigated the power, efficiency and power density as well as the temperature and the spectrum for different forward currents.
Future plans are to build an LED array to demonstrate that pumping an Nd:Glass laser is possible, as well as investigation on other LEDs.

Theoretical Methods and Simulations of the Magnetized Plasmas Stopping Power

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Interactions between ion beams and highly ionized plasmas are vital for understanding the Inertial Confinement Fusion (ICF). When particles interact with plasmas, they exchange energy via the plasma Stopping Power (SP). SP can be calculated within the dielectric formalism. However, limited plasma experiments contrast solid target studies. Moreover, if magnetic fields are present, they can alter

particle trajectories or energies. Thus, models addressing SP in magnetized plasmas are considered and compared with other methods.
Our model uses the classical dielectric formalism, this approach being outlined in references [1, 2]. This method encompasses a magnetic field, calculating the Energy Loss Rate (ELR) and effectively distinguishing slow and fast projectiles and strong and weak fields. However, it employs several models for the dielectric function. An alternative dielectric function model [3] is also employed. This model closely resembles the methodology mentioned in the previous sentences.
We compare our method with the Binary Collision (BC) formulation that constitutes another analyzed method [4]. This formulation enables the calculation of stopping power considering magnetic field effects. Unlike the dielectric formalism, it does not rely on a certain model for the dielectric function, and this method generally involves greater complexity in obtaining the energy loss straggling.
We have developed a simulation code to calculate the dynamic trajectories of ions traversing a magnetized plasma. This software includes all the forces that ions suffer during their trip through the ionized material also, the ions scatter due to random nuclear collisions with the target nuclei. In addition to the stopping, energy straggling is also an important phenomenon considered.
While progress is being made in refining the software, challenges have emerged in dealing with intricate equations and computational demands. Overcoming these challenges would significantly enhance the simulation code utility. Successful resolution of these issues would pave the way for novel investigations into particle behavior within dynamic plasma systems.

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Activities on High Energy Density Physics at Xi'an Jiaotong University

Yongtao Zhao

We will report our recent activities on high energy density physics at Xi'an Jiaotong University based on high power laser facilities and heavy ion accelerators.
1) We experimentally investigated the charge transfer process, the stopping process as well as the transportations of ion beams in plasma at XGIII laser facility as well as Heavy Ion Research Facility in Lanzhou . The target density effects are proved to significantly increase the effective charge states of carbon ions in near critical density plasma[Phys. Rev. Lett. 130, 233001(2023)]. The excited states of ions are demonstrated to play an important role determining the charge states as well as the energy loss in gas-discharge plasma[Phys. Rev. Lett. 126, 103402(2021)]. The energy loss of laser-accelerated intense proton beam is found to be enhanced by about one order of magnitude compared to individual ion stopping theory predictions due to the collective effects[Nat. Commun. 11, 5157(2020)]. The collective effects are shown to induce instabilities such as beam focusing, flapping and hollow organizations in plasma[Phys. Rev. E 101 (2020) 051203 (R)�Physics of Plasmas 29, 022303 (2022)].
2) We generated white-dwarf-atmosphere-like C-H-O dense plasma in laboratory. The emission lines were measured and compared with astro-observations [Astrop. J. 920,106(2021)�Laser and Particle Beams 2022, 6653739 (2022)]. We simulated the hydrodynamic response of matter heated by the

intense heavy ion beams from HIAF and FAIR [Phys. Rev. E. 100, 13208 (2019), Nuclear Instruments and Methods in Physics Research Section B 429, 48(2018),High Power Laser and Particle Beams 33, 012005 (2021)].
3) We experimentally studied the p11B nuclear reactions in plasma circumstance initiated by laser-accelerated intense proton beams. The reaction product yield are enhanced in plasmas compared with cold matter. The yield increases with beam intensity non-linearly and exceeds the beam-target interaction predictions[Laser and Particle Beams, 2023, (2023): 9697329, arXiv:2308.10878].
5) We generated high-current relativistic electron beam and brilliant X/□ sources through laser interaction with near critical density plasma. The electron beam has a Maxwellian distribution with temperature of about 12 MeV and cutoff energy near 90 MeV. The charge quantity is about 90nC for electrons with energy larger than 1MeV. The half-divergence angle is about 11 degree.

Measurements and Determinations for the Charge Quantity of Brilliant Electron Beams Generated Through Laser-NCD Plasma Interaction

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The laser-driven relativistic electron beam is characteristic of short pulse, high energy and large charge quantity. It has significant applications in suprathermal electron transportations, fast ignitions, electron beam radiography, and the generation of ultra-short X/γ radiation sources as well as neutron sources. We experimentally generated brilliant electron beams through picosecond-laser-NCD (near critical density) plasma interactions. The NCD plasma sample (T 17 eV, □□ 4 e20 /cc) was created through heating a foam target with nanosecond-laser-induced hohlraum radiation in the soft x-ray regime. The charge quantity as well as the spatial distribution of the electrons were dignosed with stacks of 3-mm cylindrical steel and Fuji Image Plates(IPs), that was placed at 20cm away from the source. The first-layer image plate (E>3.4 MeV) was saturated seriously, and needs to be scanned for 16 times to resolve the signals. To obtain the charge quantity, the gel values of the IP signals were converted into PSL values firstly by taking into account the scanner sensitivity, latitude, resolution settings as well as the saturation modification coefficients. Due to the fact that the response/PSL for varied electron energies are different, we performed numerical iterations to get the accurate charge quantity. The results show the electron beam has the quantity of 90 nC and 70nC for energy larger than 1MeV and 5 MeV, respectively .

Exploring the Phase Diagram and Diamond Formation of Double Shocked PET Using in Situ X-Ray Diffraction

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Diamond formation from plastics in shock compression experiments has sparked great interest in past years [1-3] for both, material science and ice-giant interiors. Experimental observations are difficult to perform and require high power lasers and bright X-ray sources to generate and probe the extreme matter conditions. In contrast to previous studies on polyethylene terephthalate (PET)[1], which focussed on single-shock drive schemes, we present in situ measurements of off-hugoniot states, applying double shocks. This way, we have mapped the regime of diamond formation in PET for a variety of different temperature-pressure conditions. The experiment was conducted at the European XFEL facility in Hamburg/Schenefeld, utilizing the new DiPOLE-100X diode-pumped high-energy laser with exceptional pulse shaping stability and X-ray diffraction diagnostics. With our studies, we provide new data for the phase diagram of carbon-hydrogen-oxygen mixtures with direct implications for the physics of ice-giant planets, extending the region of verified diamond formation to higher pressures. Furthermore, we were able to measure diamond diffraction signal for times up to 30 ns after the shock breakout, informing efforts to recover the nano-diamonds created [3].

[1] He et al. Diamond formation kinetics in shock-compressed C-H-O samples recorded by small-angle x-ray scattering and x-ray diffraction. Science Advances, 8(35):eabo0617, 2022.

[2] Kraus et al. Formation of diamonds in laser-compressed hydrocarbons at planetary interior conditions. Nature Astronomy, 1(9):606–611, 2017.

[3] Schuster et al. Recovery of release cloud from laser shock-loaded graphite
and hydrocarbon targets: in search of diamonds. Journal of Physics D: Applied Physics,56(2):025301, 2022.

Objective Functions in Isochoric Design Studies for Proton Fast Ignition

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In the Proton Fast Ignition (PFI) [Tabak et al., Ignition and high gain with ultrapowerful lasers, Physics of Plasmas 1, 1626 (1994); Roth et al., Fast Ignition by Intense Laser-Accelerated Proton Beams, Phys. Rev. Lett. Vol. 86, No. 3, January 2001] scheme an inertial fusion target is compressed to densities of the order of hundreds of g/cc using nanosecond-duration lasers. To reach the necessary temperature for ignition, a short-pulse (picosecond) laser generated high-energy proton beam of multiple MeV is focused onto the compressed fusion fuel. In conventional inertial fusion schemes, the fuel is ignited by coupling enough energy into a central hot spot, which typically creates an isobaric state between the hot spot and a colder and much denser fuel shell. In PFI the creation of a central hot spot is not necessary, due to the ignitor pulse, resulting in relaxed conditions for the fuel compression, and different constraints on the driver. This allows fast ignition designs to compress the fuel to an isochoric state at lower implosion velocity, enabling the use of more fuel mass, which is beneficial for high gain designs.
We present results of numerical studies with the goal to achieve an isochoric fuel assembly. We employ a modified version of the radiation-hydrodynamics simulation code MULTI-IFE (MULTI-IFE [Ramis and Meyer-ter-Vehn, MULTI-IFE—A one-dimensional computer code for Inertial Fusion Energy (IFE) target simulations, Comput. Phys. Commun. 203 (2016) 226–237]). The code is coupled to an optimizer that implements particle-swarm-optimization (PSO) [Kennedy and Eberhart, Particle Swarm Optimization, ICNN'95 - International Conference on Neural Networks]. We use the self-similar isochoric design by Clark and Tabak [A self-similar isochoric implosion for fast ignition, Nucl. Fusion 47 (2007) 1147–1156] as a starting point to study this class of implosions. We show the results of multiple studies with different objective functions and discuss their merits as a tool in the design process of isochoric implosions.

Alternative Hydrogen Storage Concepts

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With regard to future energy production, there is a growing need for suitable hydrogen storage

technologies in a wide range of applications.
Our poster is about alternative concepts for hydrogen storage based on GSI's SIS100 cryosorption pump.
First, the basic principles of condensation and adsorption in cryopumps are described. Furthermore the conventional hydrogen storage systems are explained and compared. Following this, the poster discusses the concept of combining adsorption storage and liquid hydrogen storage for enhanced storage times. The concept of solid hydrogen storage for improved storage density will also be introduced. Finally, our planned experiments and research work will be presented.

Observing the Interaction of Shocks With Interstellar Clouds in the Lab

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The interaction of shock waves with interstellar clouds can either trigger star formation or completely strip the interstellar cloud of its mass. It therefore plays a crucial role in the evolution of our Universe. In a recent beamtime at the LULI2000 laser, we drove a shock wave into a plastic foam with an inserted aluminum oxide sphere. The interaction between the shock wave and the sphere can model a shock in the interstellar medium passing through an interstellar cloud. Time-resolved high-resolution X-ray radiography images the destruction of the sphere and observes the hydrodynamic features involved. The measurement results are compared to radiation hydrodynamic simulations (FLASH) and discussed in an astrophysical context.

Optical Undulator Free Electron Laser and Single-Element Integrated X-Ray Optical System

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The reporter briefly reports the latest progress of his team in the research of optical undulator free electron laser and single element integrated x-ray optical system. The advanced material testing technology research center of Shenzhen University of technology has prepared to build the accelerator and X-ray optics laboratory. Its main research directions are: 1. Explore a new ultrafast X-ray source based on the interaction between electron accelerator and strong laser; 2. Develop a new X-ray optical system based on new principles. The former attempts to find a unique technical way in the exploration of new X-ray light source technology, while the latter hopes to establish a technical method to make the X-ray optical system miniaturized and lightweight while maintaining or improving its technical indicators. The latter research is expected to be the first to be applied in the diagnosis of laser driven high-order harmonic X-ray sources.