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Introduction

WP6 “High-power lasers: Technology development for future multi-PW laser facilities” has the following objectives

- Develop new optics and metrology technologies as key technological foundations for future multiPW (peta watt) laser facilities
- Use relativistic plasma mirrors as light condensers to approach Schwinger limit
- Design a low number of shots spatio-temporal diagnostics device for ultrashort & ultraintense laser pulses at multi-PW laser facilities with low repetition rates
- Train researchers and engineers in laser science, metrology and applications

Task 6.3 deals with “Training and scientific exchange”, under joint responsibility of Laserlab-Europe AISBL and ELI-ERIC. In particular, Laserlab-Europe provides a platform for dedicated knowledge sharing and training on the topics of intense laser pulse propagation, pulse contrast enhancement, and pulse metrology. This will be realized through a series of events in which these relevant topics will be discussed among the partners in conjunction with experts from Laserlab-Europe and external internationally renowned instructors. The regularity of these training events will provide a sustainable laser science forum in which knowledge and state-of-the-art results are shared and best practices are developed.

The training events had been conceived as on-site trainings with hands-on sessions in partner labs, so the Covid-19-related restrictions on travels and personal meetings first induced a postponement of the planned trainings. When it became clear that planning of trainings on site would continue to be subject to risk of cancellation at short notice, and different formats of online events had been tested as partial replacements for on-site trainings, the Laserlab-Europe community proposed to organise online training events on suitable topics, such as “pulse propagation – simulation codes” and “high energy/high intensity metrology”.

Training event on “Modelling of ultra-intense laser propagation in plasmas and laser-plasma accelerators”

A first online training event has been organized on "Modelling of ultra-intense laser propagation in plasmas and laser-plasma accelerators: fundamentals" on 26 to 29 April 2022, by Laserlab-Europe partner IST, Lisbon, Portugal.

Organization: GoLP/IPFN/Instituto Superior Técnico, Lisbon, Portugal
Coordination: Jorge Vieira, Ricardo Fonseca
Instructors: Jorge Vieira, Ricardo Fonseca, Miguel Pardal, Bernardo Malaca
Admin Support: Cláudia Romão, Ana Luísa Matias

The training event was dedicated to the fundamentals of computational modelling of intense laser pulse propagation in plasma, and applications to compact laser plasma based accelerators. Laser

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plasma accelerators are one of the most exciting applications of intense lasers, and computational modelling plays a critical role in the design and optimization of laser plasma accelerators.

The target group were PhD students, post-docs as well as researchers in laser-plasma interactions, with both experimental and theoretical backgrounds, aiming to develop their know-how on computational techniques commonly used in laser propagation in plasmas and intense laser-plasma interactions. The number of participants was limited to ~20 participants. Applicants were selected following the submission of a brief letter of motivation, providing their name, affiliation and position (student/scientist, etc.) and explaining their interest in the field.

In total 27 applications were received and accepted. Overall, 23 attendees were actively participating throughout the full 4 days of the training. One participant attended on one day only, and three applicants from India and the US did not attend, presumably due to timing issues. The majority of the participants were affiliated with Laserlab-Europe and ELI facilities, but also participants from other European laboratories, from Israel and a participant from the University of Khartoum, Sudan, took part. The group consisted of three Master students, 15 PhD students and 6 postdoctoral researchers. Six participants (25%) were female.

The event took place over the course of 4 days, with a 2 hour lecture per day where participants learned the basics of pulse propagation in plasma, the principles of state of the art laser-plasma computational tools, how to use these tools and perform data analysis. The computational tool that was used was the open-source ZPIC code (https://ricardo-fonseca.github.io/zpic/) developed by the instructors. ZPIC is a fully relativistic, electromagnetic particle-in-cell code that is specifically designed for plasma physics education. ZPIC builds on the state-of-the-art particle-in-cell OSIRIS, featuring all the main ingredients of that code, and allowing for use in a Jupyter (Python) notebook environment.

The PIC scheme is a standard tool in laser-plasma research today, and in particular in laser-plasma accelerators. Participants learned the fundamentals of the PIC algorithm, as well as basic skills in using these codes for their research and for laser-plasma/accelerator applications. Ideally participants were expected to have some experience/programming skills in C and Python but the training event could also be followed with beginners' expertise.

The lectures and hands-on sessions were entirely remote, with remote support/discussion over a Slack channel. Participants needed to have their own laptop or desktop computers and good internet connection. Instructions for software installation have been provided during class. Background and training material for each day was provided through the event's webpage.

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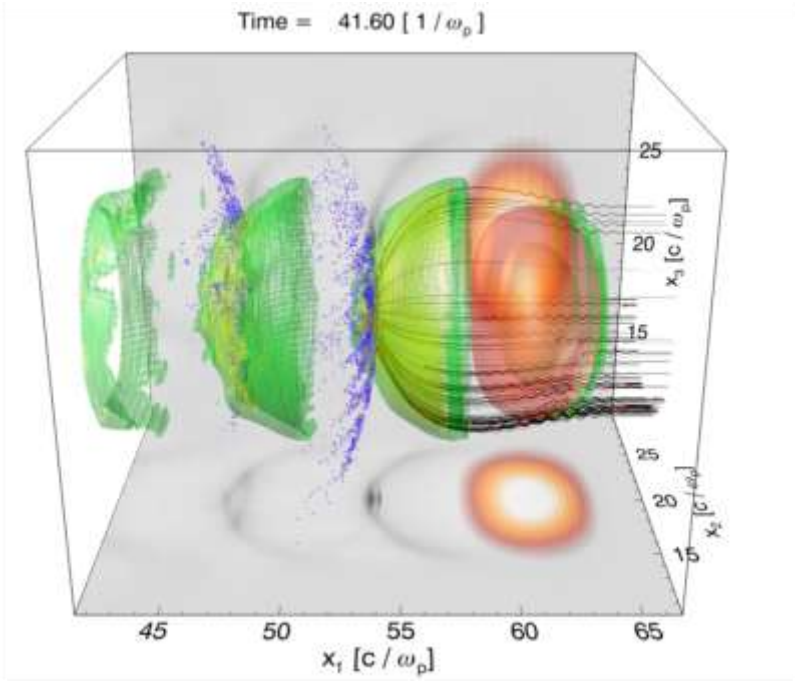

Figure 1 – 3D Simulation of a laser wakefield accelerator, showing the laser driver (yellow/orange), the plasma wave (green) and accelerated particles tracks.

Detailed programme

Session 1 - Tutorial + hands on: PIC codes and ZPIC installation.

- Tutorial: Basics of PIC simulations (the PIC loop, field solver, particle push, units).
- Tutorial + hands on: ZPIC installation and on how to use it (input file, diagnostics, plotting data).

Session 2 - Tutorial + hands on: Laser dynamics and plasma accelerators: an introduction.

- Introduction to laser wakefield accelerators (plasma waves, acceleration, wakefield excitation with intense lasers).
- Hands-on: Numerical modelling of laser-plasma interactions.

Session 3 - Hands on: Basics of PIC simulations.

- Laser propagation in plasmas
- Advanced Visualization and Data analysis
- Challenges for participants

Session 4: Participant flash presentations.

- Challenges results
- Wrap-up

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Conclusion

The training event was very well received by the participants, and the organizers received very positive feedback. The chosen schedule of one session per day over a period of four days, combined with the (strictly) online format, was successful, with participants following the live sessions closely, with several questions asked (and answered) during these sessions, and then proceeding to do autonomous work. The slack channel also provided most of the support/discussion outside of these sessions, with email also being used often for the same purposes.

To the best of our knowledge, all the participants were able to achieve the main goals of this training event, which were to understand the fundamentals of PIC simulations, to get ZPIC up and running on their laptops, and to be able to set up and run plasma-based accelerator simulations, as well as to visualize and interpret the results adequately. In the final sessions, several participants presented their results of the "challenge" problems, where they had been asked to independently select a particular plasma accelerator / laser propagation scenario and explore it with the computational tools provided, with excellent results.

The main difficulty that the participants had was related with compiling the code on their own computers, which requires some technical knowledge, particularly in Windows environment. However, given that the participants could use the code using a Docker image instead (https://hub.docker.com/repository/docker/zamb/zpic), this did not represent any sort of impediment. For future events, the use of an online resource provider such as mybinder.org or Deepnote is being considered.

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