Progress Update

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WP6 Meeting

23rd May 2023

ROYAL HOLLOWAY UNIVERSITY OF LONDON

BDSIM

LhARA Laser-hybrid Accelerator for Radiobiological Applications

JAI John Adams Institute for Accelerator Science

Simulation Updates

- Simulation updates:
  - Rechecking 10cm target housing simulations
    - Screen vs tout output & observed emittance growth
    - No discrepancy seen – approach validated
    - Validation against alternative code would be useful
  - Optimisation of optics configurations for varying spot sizes
    - Recommence work – ongoing. Review next week.
  - List of studies required for baseline comparison?
    - Collimation
    - Deliverable dose rate calculation
    - Loss estimates
    - Transverse profile uniformity

General Updates

- Upcoming talks:
  - ISIS2/LhARA common themes Meeting (1st June)
    - "LhARA phase I as a proton source" – 20m (17+3)
    - Slides underway, will send to WP6 asap. (Next Tues?)

  - IOP PAB (29th – 30th June)
    - "LhARA: The Laser-hybrid Accelerator for Radiobiological Applications" – 15m (13+2)
      - Tweak JAI AB talk – good collaboration overview.

- Summer Student:
  - Lilli Platt, 2nd yr RHUL BSc student
    - Starts on Mon. 3rd July – 6 weeks
    - Project description deliberately broad – choice of studies
    - Compiling material for pre-project reading

IPAC Update

- LhARA WP6 paper accepted
  - Minor editor fixes - mostly reference formatting

- Contributions of interest:
  - ION ACCELERATION BY LASER-MATTER INTERACTION: STATUS AND PERSPECTIVE WITH THE UPCOMING I-LUCE FACILITY AT INFN-LNS
    - Poster – see last slide
  - FOCUSING OF HIGHLY CHARGED ION BEAMS USING GABOR-LENSES
  - IMPROVEMENT OF BEAM TRANSPORT IN HIGH ENERGY TRANSFER LINES USING GABOR-LENSES
  - **Dosimetry and first radiobiological assay of multi-Gy, multi-MeV TNSA proton beam with ultrahigh dose-rate**
    - TUPL615 - paper not available yet
    - Author link

Summary

- Done:
  - IPAC

- Ongoing:
  - Rechecking target housing beam transport & emittance calculations
  - Re-running of stage 1 beam transport simulations
  - Re-run optimisation routines with updated beam

- Todo:
  - Comparison to baseline design
  - Write talks for:
    - ISIS2/FETS/LhARA FFA discussion
    - IOP PAB
  - Update models of alternative baseline design (v5.5)
  - Quads only model (v6.0)
  - Develop OPAL model of FFA – need JP input.

Interesting IPAC Posters

THPA179

IPAC23

Ion aceleration by laser-matter interaction: status and perspective with the upcoming I-LUCE facility at INFN-LNS

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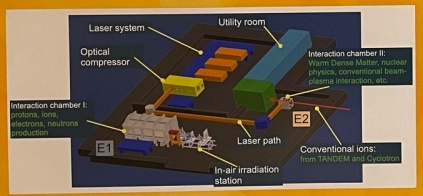
The acceleration processes based on the coherent interaction of high-power lasers with matter is, nowadays, one of the most interesting and promising topics in the field of particle acceleration, becoming day by day a real alternative to conventional approaches. Some of the extraordinary peculiarities of laser–matter interaction, such as the production of multi-species (gamma, X-rays, electrons, protons, ions, neutrons, positrons), short-pulsed and intense beams are particularly attractive for many applications as well as for fundamental physics.

I-LUCE - INFN Laser induced particle acceleration

The potential for developing compact, high-brightness particle and radiation sources have given a strong impetus to the development of the underpinning laser technology, including increasing the efficiency and repetition rate of the lasers. A result of this technological development can be seen in the new generation of ultra-fast and high-power laser systems working at a high repetition rate which have been built across Europe. A new high-power laser facility called "I-LUCE" (INFN Laser indUced radiation acCEleration) will be realized at LNS-INFN (Laboratori Nazionali del Sud – Istituto Nazionale di Fisica Nucleare) in 2025. I-LUCE is currently under construction at LNS-INFN and will allow particle acceleration and the study of nuclear reactions in plasma. The facility realisation is funded by three PNRR (Piano Nazionale Ripresa Resilienza) Italian programs: EuAPS (EuPRAXIA Advanced Photon Sources), Samothrace (SicilIAn MicronanOTecH. Research And Innovation) and ANTHEM (Advanced Technologies for Human- centrEd Medicine).



High-Power Laser

The whole laser system, from the main oscillator up to the compressor vacuum chamber, will be installed inside a clean area, where an ISO7 cleaning standard will be ensured. The Ti: Sapphire laser system will consist of a first section, composed of a femtosecond oscillator and a front-end (including a stretcher, regenerative amplifier, pump lasers, an XPW module and a first amplifier) and two different outputs: the first one will be a 40-50 TW, high repetition rate (HRR), beamline (25 fs, 1.3 J, 10 Hz), while the main beamline will be a 320-350 TW, low repetition rate (LRR), laser (25 fs, 12 J, 1 Hz). A laser control system, devoted to remotely controlling and monitoring all the laser components and sub-systems (main oscillator, booster, amplifiers, compressor, etc.) together with all the devices of the diagnostic system, will be installed in the PCs of a dedicated control room.

	HRR	LRR
Laser power [TW]	≥ 40	≥ 320
Repetition rate [Hz]	≥ 5	≥ 1
Emission wavelength [nm]	800 ± 10	
Energy per pulse [J]	≥ 1	≥ 7
Pulse duration [fs]	≤ 25	
Energy stability [rms]	≤ 1.5%	
Strehl ratio	> 80% with deformable mirrors	

Experimental area

The I-LUCE facility of the INFN-LNS will serve two experimental areas called E1 and E2.

The E1 experimental room will be mainly dedicated to particle acceleration. A beamline to select, transport, and focus proton beams with energy between 5-60 MeV will be installed and optimised to perform in-air experiments. A station for electron acceleration in LWFA (Laser Wakefield Acceleration) regime will also be installed. This will be equipped with a gas-jet system, an online diagnostic, and a selection system able to select electrons with energies up to 800 MeV. In addition, stand-alone experiments with intense laser beams will be carried out for several studies such as neutron production or X-ray laser generation.

The E2 experimental room will provide the worldwide unique combination of intense laser radiation with heavy ion beams generated by the Superconductive Cyclotron and Tandem accelerators (already installed at LNS), opening the door for interesting experiments in the field of plasma physics, nuclear physics, and atomic physics.

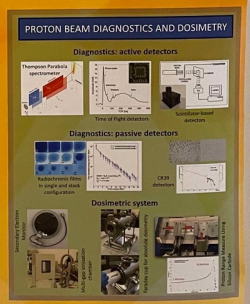
For moderate laser beam intensities (up to 50 TW) experimental room E2 will be also devoted to performing experimental runs dedicated to nuclear fusion and stopping power in plasma studies.

Source characteristics

The I-LUCE facility of the INFN-LNS will be available for accelerating a wide portfolio of beams, including protons, electrons, ions, γ, X-rays and neutrons, through the use of different laser-target interaction techniques.

Protons	
Energy [MeV]	up to 100
Number of particles per pulse	6.4E10 at 60 MeV
Number of particles per pulse	1.7E11 at 30 MeV
Beam divergence	± 20°

Electrons	
Maximum energy [GeV]	2
Energy spread (FWHM)	10%
Number of particles per pulse	1E+09
Beam divergence [mrad]	from ± 2 up to ± 20



Future Perspectiveness

The I-LUCE facility will be fully operative at the LNS within 2026, delivering beam time for nuclear, astrophysics and multidisciplinary research and open access for collaborative national and international projects focused on laser-driven particle acceleration and biomedical application, as well as studies devoted to warm dense matter states. The main features of the I-LUCE installation were described in this paper, together with the main expected characteristics of both proton and electron beams. An upgrade of the laser system, up to 500 TW peak power, is expected starting since 2030.