

Laser-driven Electron Acceleration

The Extreme Light Infrastructure (ELI) is the world's largest and most advanced collection of high-power lasers. As an international user facility dedicated to multi-disciplinary science, ELI provides access to world-class high-power, high-repetition-rate laser systems and enables cutting-edge research in physical, chemical, materials, and medical sciences, as well as breakthrough technological innovations.

Ultra-short high-energy laser pulses at ELI are used to create plasma with extremely high electric and magnetic fields that allow acceleration of particles at relativistic energies. The generation of stable beams of charged particles with favorable properties and high energies has a wide range of applications.

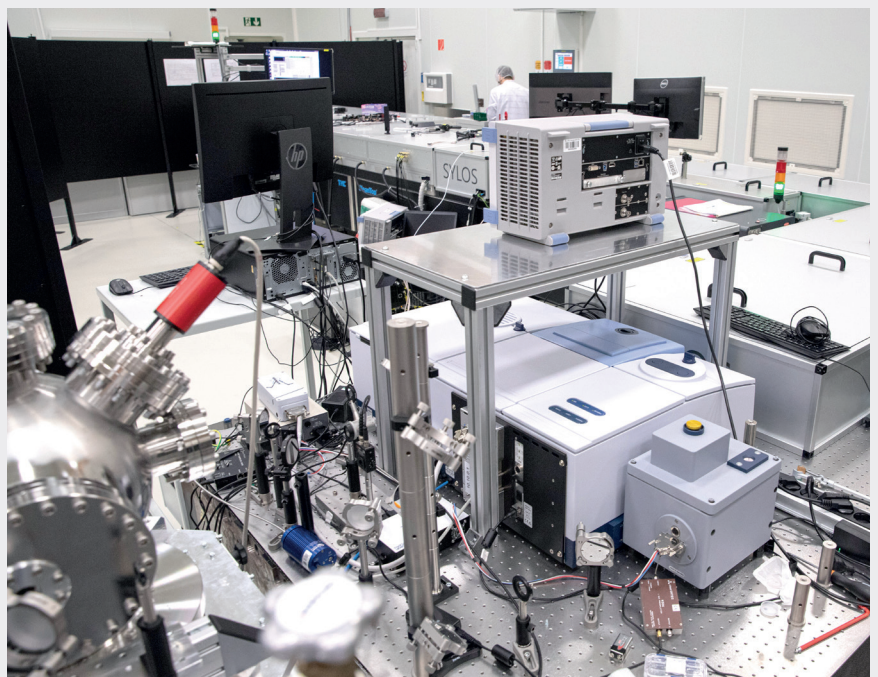
ALFA



The ALFA (Allegra Laser For Acceleration) at the ELI Beamlines Facility is a laser plasma electron accelerator driven by the kHz L1-Allegra laser. The optical setup available at ALFA enables users to carry out laser-matter interaction experiments at relativistic intensity ($\sim 5 \times 10^{18}$ W/cm²) and, in addition, delivers ultra-short electron beams (few fs) at a tuneable frequency (up to 1 kHz) and with tuneable energy (a maximum of 50 MeV). Such unique capability has already been demonstrated at ALFA for the optimisation of kHz laser wakefield plasma acceleration to deliver ultra-relativistic (<50 MeV), ultra-short (few fs) electron beams intrinsically synchronised with additional laser pulses. These unique features can be applied in the fields of very high energy electrons (VHEE) radiotherapy and dosimetry, x-ray generation by Thomson scattering and betatron radiation, ultra-fast radiobiology and radiochemistry, and radiation effect to electronics research.

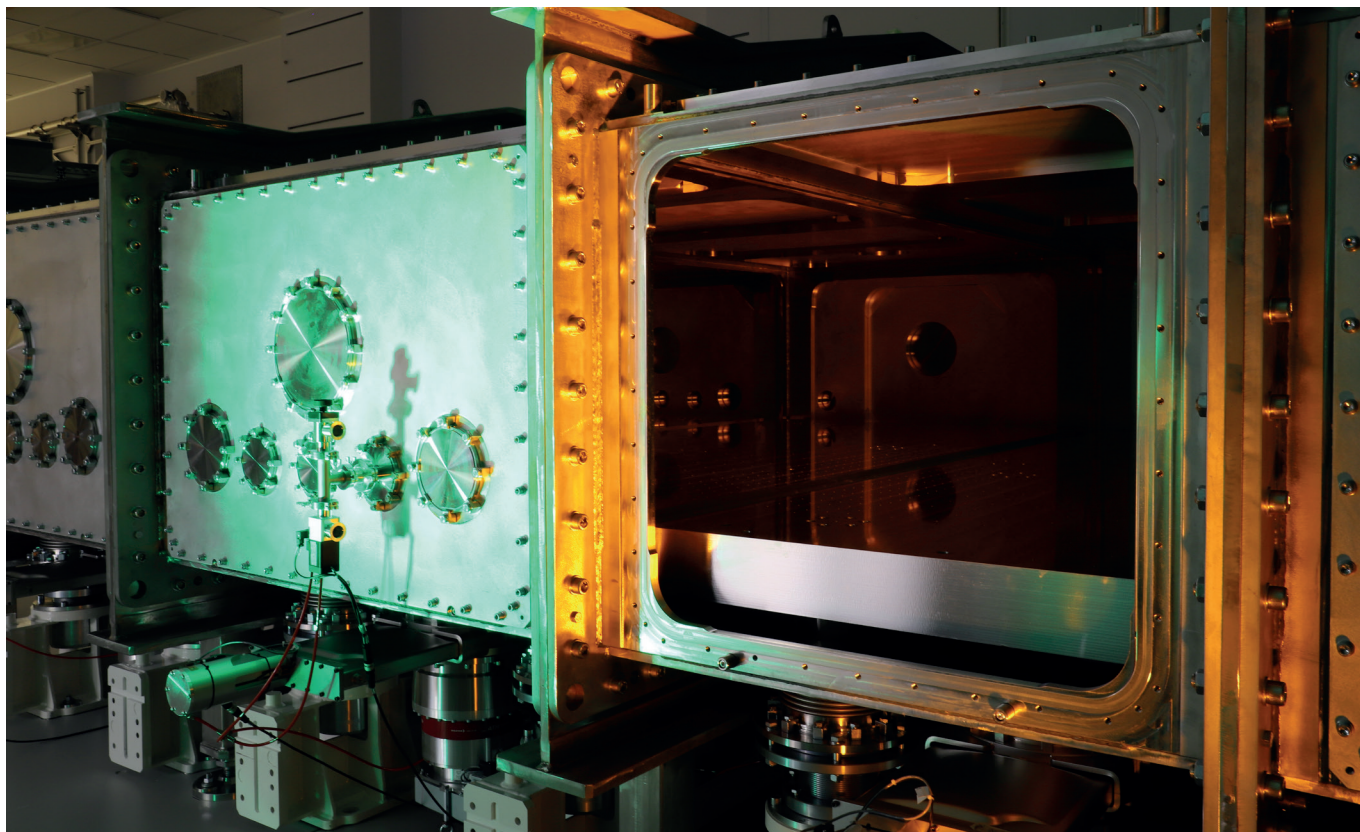
eSYLOS and ePW

The ELI ALPS Facility hosts two laser wakefield acceleration electron beamlines named eSYLOS and ePW. The eSYLOS beamline is driven by the SYLOS laser system. Planned user applications of the eSYLOS accelerator include radiobiology and ultrafast soft X-ray spectroscopy. The ePW beamline, which is driven by the HF PW laser system, is a GeV electron accelerator that will be located in the HTA bunker. The ePW is primarily foreseen as a betatron X-ray source to produce beams of hard X-rays in a broad spectral range from 5 keV up to 100 keV. User applications of such X-ray beams include phase-contrast imaging, micro-computed tomography and other application areas of science, technology and medicine.



ELBA

ELBA (Electron Beam Accelerator for fundamental Sciences and Applications) at the ELI Beamlines Facility is the first all-optical GeV electron - PW laser collider at 10 Hz. It is designed to enable the experimental investigation of fundamental nonlinear Quantum Electrodynamics (QED) processes as vacuum polarisation and Breit-Wheeler. Users may apply to work on the electron-laser collider experiments, or to use the GeV electron beam.

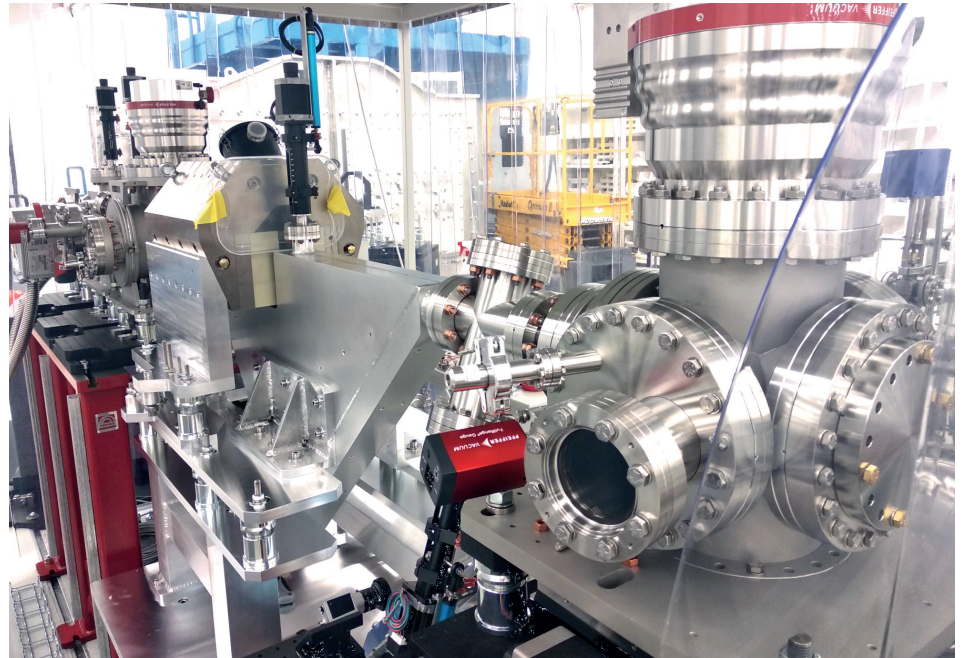


Beamline	Parameters of the beamline	Primary source (laser)	Parameters of the laser	Availability
ELI ALPS eSYLOS	Repetition rate: 1 kHz Electron beam energy: 10-50 MeV Charge: few pC	SYLOS laser system	5 TW, 36 mJ, 6.3 fs, 1 kHz	User-ready by Q3 2023
ELI ALPS ePW	Electron beam energy: 1-2 GeV Charge: 100 pC Divergence: 2 mrad	HF PW laser	1.4 PW, 10 J, 25 fs, 10 Hz	User-ready by Q4 2023
ELI Beamlines ALFA	Repetition rate: 1 kHz Electron beam energy: >50 MeV Divergence: 1-2 mrad 55 mJ (100 mJ planned) 16 fs on target	Laser L1-ALLEGRA	5 TW, 100 mJ, <15 fs, 1 kHz	Pilot experimental results available
ELI Beamlines ELBA	GeV electron-PW laser collider	L3-HAPLS	1 PW, 30 J, <30 fs, 10 Hz	User-ready by Q3 2023

LUIS – towards a compact and cost-effective free electron laser (FEL)

The technique of laser wakefield acceleration (LWFA) has high potential for a novel compact FEL driver, in particular with recent progress in laser technology, acceleration gain, and breakthroughs in electron beam quality improvement.

The LUIS project at the ELI Beamlines Facility will be capable of generating high-brilliance coherent photon radiation in the EUV wavelength range, reaching energy saturation only in a single-unit planar undulator with the length of 4 meters. This enables construction of a compact and cost-effective FEL suitable for user applications with an output peak photon brilliance comparable to the existing linear-accelerator-based EUV-FEL facilities such as FLASH (Germany) and FERMI (Italy).



	LUIS incoherent case	LUIS coherent case	
		EUV LPA-FEL	'Water-window' LPA-FEL
Electron beam energy [MeV]	400 - 600	300 - 400	800 - 1300
Bunch charge [pC]	30	50	50
RMS bunch duration [fsec]	3	5	5
Repetition rate [Hz]	Up to 50	50	Up to 100
Photon energy [eV]	290 - 650	32 - 56	235 - 525
Radiation wavelength [nm]	4.2 - 1.8	38 - 22	5.2 - 2.4
Radiation bandwidth [%]	1	~ 0.3	< 0.2
Photon flux per (mrad ² /0.1% bw)	(3 - 6) × 10 ⁵	~ 5 × 10 ¹²	(2.5 - 4) × 10 ¹²
Peak brilliance photons/pulse/mm ² /mrad ² /0.1%bw	(1 - 3.5) × 10 ²⁰	~ 5 × 10 ²⁹	~ 10 × 10 ²⁹
Photon pulse power [GW]	tbd	Up to 5	Up to 2
Undulator length / Saturation [m]	0.5	~ 4	20 -30

Primary source (laser)	Parameters of the laser	Current status
ELI Beamlines L2-DUHA	300 - 1200 MeV , TW , 2-4 J, 25 fs, 20 Hz (50 Hz, aiming 100 Hz)	Under development

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IMPULSE



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