Status of the CLARA Facility at Daresbury Laboratory and exploitation for advanced accelerator research

Science and Technology Facilities Council

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1. Introduction

CLARA (shown in **Figure 1**) is an ultrabright 250 MeV electron beam test facility under development at STFC Daresbury Laboratory.[1]

CLARA was originally conceived to test advanced Free Electron laser schemes but has since become a unique facility for user-led experiments in a wide range of disciplines.

We report the status of the CLARA facility, including details from our last user run (2021-22), an update on construction currently underway, and prospects for future user exploitation of CLARA due to begin early 2025.

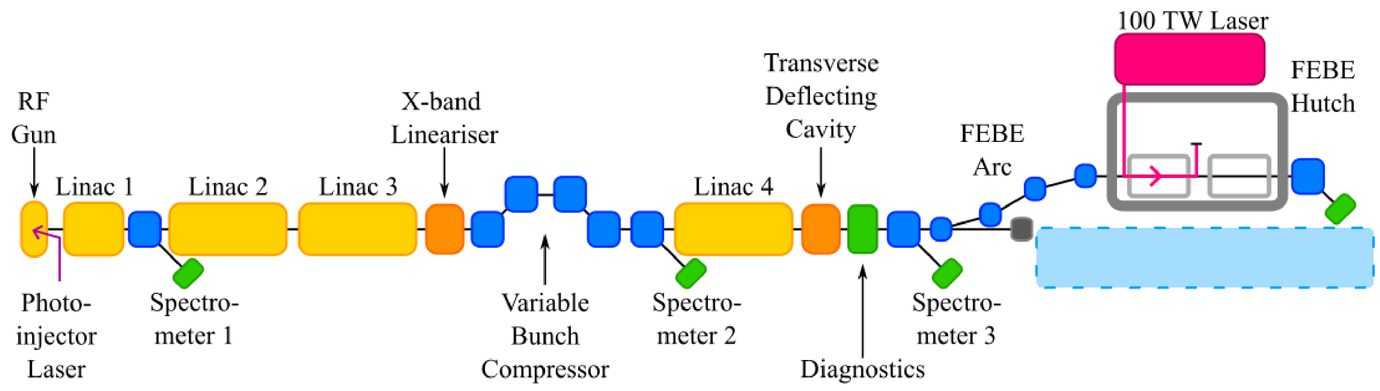

Figure 1: Schematic layout of the CLARA accelerator and FEBE beamline (including FEBE hutch and 120 TW laser system) and space reserved for potential future applications (shaded blue area).

Parameter	Commissioning target	
	High charge	Low charge
Beam energy [MeV]	250	
Repetition rate [Hz]	100	
Charge [pC]	250	5
Bunch length [fs]	100	50
Transverse RMS, x [μm]	100	20
Transverse RMS, y [μm]	100	20
Energy spread [%]	<5	<1
Norm. emittance, x [μm.rad]	5	2
Norm. emittance, y [μm.rad]	5	2

Table 1: Beam parameter targets for CLARA commissioning (scheduled to begin November 2023) as defined at the focus of the first FEBE interaction chamber.

2. Advanced acceleration at CLARA (2021-2022)

The last user exploitation of CLARA was held between October 2021 and April 2022. It utilised the RF Gun and Linac 1 to deliver 35 MeV beam at 10 Hz. Combined laser-electron experiments were performed with a 10 TW laser in a dedicated target area.

141 shifts were requested out of 70 available, with access via a beam time allocation panel. 10 experiments were awarded beam time.

Approximately 50 % of shifts awarded were for advanced acceleration concepts, including dielectric wakefield acceleration[2] (**Figure 2**), laser wakefield acceleration[3] (**Figure 3**), THz acceleration and plasma diagnostics.

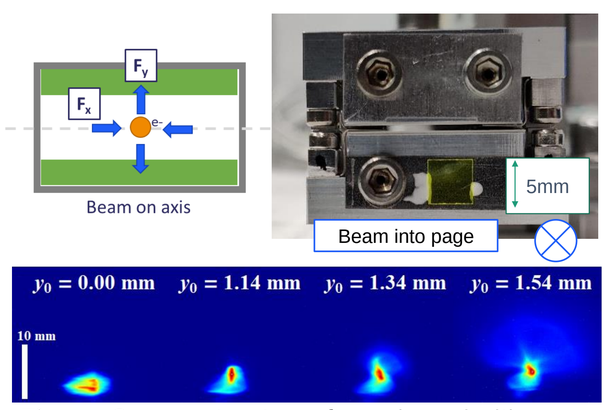

Figure 2: Investigation of quadrupole-like wakefields in a dielectric wakefield accelerator (DWA); experiments were performed in 2021 in which the CLARA beam (35 MeV, 85 pC) was transported through a variable gap dielectric-lined (200 μm quartz) planar structure (200 mm long), with varying offset, and the beam profile measured downstream (bottom).

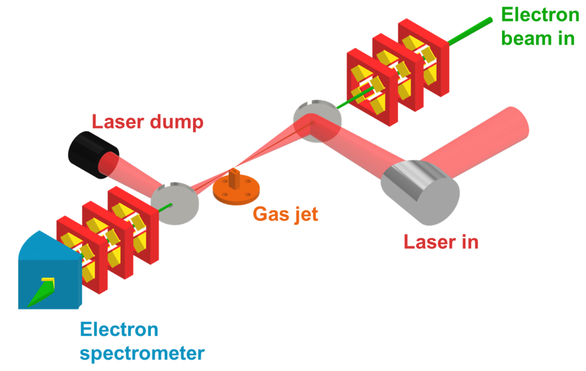

Figure 3: External injection of CLARA electron bunches into a laser-driven wakefield (linear regime); a proof-of-principal experiment was performed in 2021 in which electron bunches at 35 MeV (20 pC, $\sigma_r = 35$ μm, $\sigma_z = 450$ μm) were injected into a laser-driven wakefield ($n_e = 2\times10^{18}$ cm^{-3}, $\lambda_p = 23$ μm) and energy broadening observed.

3. Status (2023)

First beam from the high repetition rate gun (HRRG) was demonstrated at 100 Hz in March 2023 (3 MeV for 1.25 μs RF pulse length, 5.2 MW klystron output); further gun commissioning activities are planned.

CLARA is currently shut down for installation of modules. Construction is nearly complete, with all modules on the main line installed (**Figure 4**), and remaining activities focussed on a separately shielded user station.

The user station will include a 5 Hz, 120 TW laser (Arco, Amplitude) for advanced accelerator experiments; installation of the laser will be complete October 2024 and ready for exploitation early 2025.

Commissioning of the completed accelerator will begin November 2023, and progress towards achieving the beam parameter targets listed in **Table 1.**

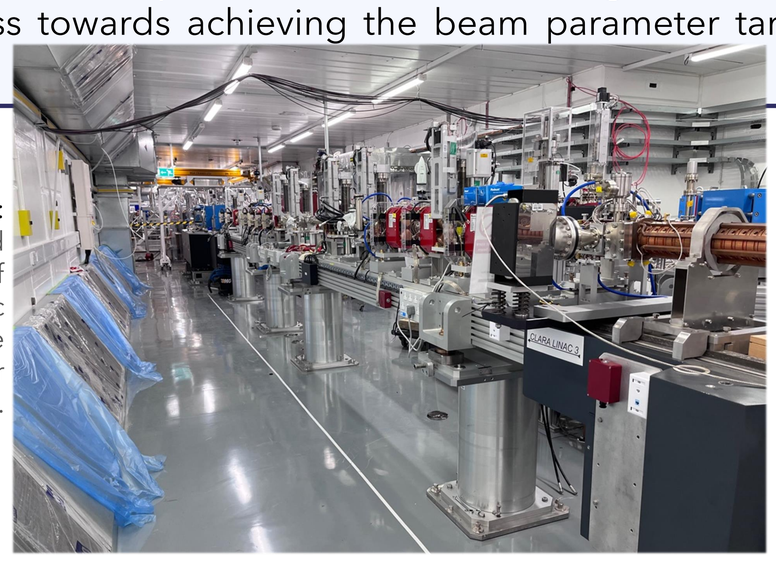

Figure 4: Completed installation of CLARA linac modules in the main accelerator hall.

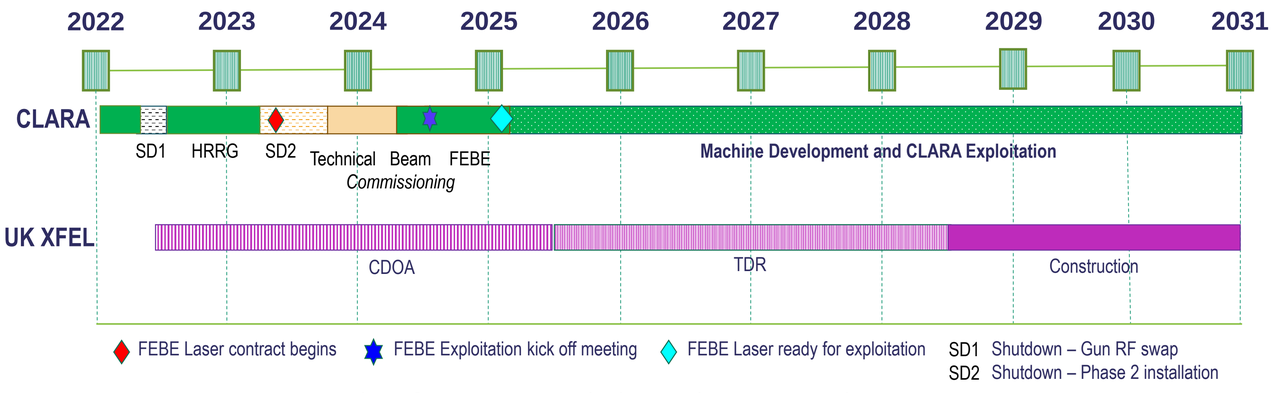

Figure 5: Timeline for current and planned CLARA and UK XFEL activities.

4. Future operation and access to CLARA (2025+)

CLARA will begin an operations for user exploitation early 2025. A call to the community for the first exploitation period is expected to be published mid-2024. A timeline of future CLARA activities is shown in **Figure 5.**

Access to the facility will be free at the point of entry and mediated by an access panel based on scientific merit and technical feasibility. Potential users are encouraged to contact STFC (see below) to discuss the capability of CLARA and ideas for future experiments.

User exploitation will be interspersed with brief periods of machine development. The goal of machine development will be to progress beam parameters beyond the commissioning targets outlined in Table 1 and increase the repeatability and reliability of beam delivery.

STFC is currently undertaking a conceptual design and options analysis (CDOA) for UK XFEL[4]: a project to deliver a next generation hard x-ray free electron laser. CLARA exploitation will run parallel to an anticipated technical design study for UK, during which CLARA may be used to also support prioritised R&D activities.

References

[1] D. Angal-Kalinin *et al.*, Physical Review Accelerators and Beams **23**, 044081 (2020)
[2] Y. Saveliev *et al.*, Physical Review Accelerators and Beams **25**, 081302 (2022)
[3] L. Reid *et al.*, presented at IPAC'23, Venice, Italy (2023)
[4] D. Dunning *et al.*, in Proceedings of IPAC'23, Venice, Italy (2023)

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For further information: please contact Edward Snedden