Overview of the Central Laser Facility (CLF)

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Introduction

The CLF is a world leading centre for research using lasers in a wide range of scientific disciplines. This section provides an overview of the capabilities offered to our international academic and industrial community.

Vulcan

Vulcan is a versatile high power laser system that is composed of Nd:glass amplifier chains capable of delivering up to 2.6 kJ of laser energy in long pulses (nanosecond duration) and up to 1 PW peak power in a short pulse (500 fs duration) at 1053 nm. It can currently deliver up to eight beam lines. Two of these beam lines can operate in either short pulse mode or long pulse mode, while the remaining six normally operate in a long pulse mode. The short-pulse can be directed to two different target areas, enabling sophisticated interaction and probing experiments, with all eight beamlines available to one target area (TAW).

The installation of the new short-pulse OPCPA beamline (VOPPEL) continued through this year. This beamline aims to demonstrate a PW-level pulse (30 J in 30 fs) OPCPA system to the Vulcan Petawatt Area (TAP). The compressor chamber was installed into the experimental area, but the final folding chamber arrangement was not able to be installed.

Gemini

Gemini is a dual-beam petawatt-class Ti:Sapphire laser system that provides unique capabilities for relativistic laser-matter interactions and secondary source production. Gemini is one of the leading centres for laser-driven plasma accelerators and applications.

In the reporting year, ATA2 was closed for user operations to set it up for EPAC prototyping and testing. Part of this work involved separating ATA1 (the old Artemis area) from ATA2 in terms of laser interlocks, and moving the short pulse probe into ATA1 in order to have a separate laser system in there for EPAC component testing.

Gemini had a significant system access period to replace the pump lasers for its third Amplifier. Following this installation, Gemini has continued to operate, delivering four experiments in TA3.

Target Fabrication

The Target Fabrication Group made the majority of the solid targets shot on the CLF's high-power lasers, and also supported target design for the academic access on the Orion Facility at AWE. Commercial access to target fabrication capabilities was available to external laboratories and companies via the spinout company Scitech Precision Ltd. The group also supported the Lasers for Science Facility (LSF) with microfabrication capabilities to enable their experimental campaigns, and provided support for the wider STFC community with micro-fabrication.

A range of microtarget types were produced to enable the exploration of several experimental regimes. Fabrication techniques included thin film coating, precision micro-assembly, laser micromachining, and chemistry processes, all verified by sophisticated characterisation. This year saw the completion of the MEMS targetry facility as a high repetition rate component manufacturing capability. The enhancement of the advanced capabilities in this area, as well as further development in single point diamond machining, enabled

the Group to support high profile experiments in the US for the first time. The Group's processes and component tracking system provided a high level of traceability and the group contributed to a number of publications, either directly as a co-author or by providing critical characterisation data for targets that were supplied.

The high repetition-rate tape drive project matured into a commercial product, which was provided to a number of international facilities commercially and also collaboratively through the European IMPULSE project. This provided the group with crucial data on EMP and x-ray shielding for eventual fielding on EPAC. Development of the liquid target system for EPAC was a high priority, with designs for nozzles and catching systems being explored, and a collaboration with Queen's University Belfast and SLAC National Accelerator Laboratory started to develop systems for testing in the CLF.

Advanced 3D printing has been added to the capabilities in Target Fabrication, with a system that has 5 µm resolution being installed in the laboratory. The Group is able to produce target components on a short lead-time with high accuracy and with the ability to make modifications to designs within a few days. Targets with additive manufacturing (AM) components have already been fielded on all of the CLF facilities.

Theory and Modelling

The Plasma Physics Group supports scheduled experiments throughout the design, analysis and interpretation phases, as well as users who need theoretical support in matters relating to CLF science. PPG supports principal investigators using radiation hydrodynamics, particle-in-cell, hybrid and Vlasov-Fokker-Planck codes, as well as by providing access to large-scale computing (SCARF).

Strong support of users throughout this period has continued, including the provision of the PRISM suite. Alongside the core mission of the PPG, the group continues to engage with the academic community to contribute to Laser fusion research.

Artemis (Research Complex at Harwell)

This was the second year of operations for Artemis in the Research Complex, following the lab move and completion of the upgrade project.

The new XUV beamline for the 100 kHz laser system was fully aligned and commissioned, and is now delivering user experiments. The new beamline enables smaller XUV spot sizes, plus better energy and angular resolution due to reduced space charge. The Artemis team commissioned a novel analyser, which enables the measurement of two dimensions of electron momentum space, for time-resolved photoemission. The team also added new experiments using high harmonic generation from solid materials as a spectroscopic technique to the portfolio. The first paper from an experiment in the new labs was accepted by Physical Review Letters.

Following the award of the £17.2M HiLUX project, the Artemis team has worked to prepare for project kick-off by preparing tenders for the new laser system, which will have both high average power for harmonic generation and tuneable UV-IR pulses, and the new momentum microscope, and they are starting recruitment.

Ultra (Research Complex at Harwell)

The structural dynamics facilities at Ultra explore molecular structure during changes, such as chemical reactions, or in complex environments. Ultra's unique combination of multiple laser amplifiers provides light across UV to IR, spectrally narrow and broad, measuring dynamics across femtoseconds to seconds, to address a diverse portfolio of scientific problems. The scientific themes span the dynamics of drug binding and protein folding, to structural changes in battery charging and catalytic cycles. The available techniques provide highly sensitive time-resolved vibrational and electronic absorption spectroscopies or Kerr-gated Raman spectroscopy to observe weak signals obscured by strong emission from samples.

Octopus (Research Complex at Harwell)

In the imaging area, the Octopus cluster offers a range of microscopy stations linked to a central core of pulsed and CW lasers, offering "tailor-made" illumination for imaging. Optical resolution techniques offered include total internal reflection (TIRF) and multi-wavelength single-molecule imaging, confocal microscopy (including multiphoton), fluorescence energy transfer (FRET), fluorescence lifetime imaging (FLIM), and Light Sheet Microscopy. Super-resolution techniques are also available: 2D and 3D Stochastic Optical Reconstruction Microscopy (STORM), Photo-activated Localization Microscopy (PALM), Structured Illumination Microscopy (SIM), gated 3D Stimulated Emission Depletion Microscopy (STED), 3D MINFLUX, and super-resolution cryo-microscopy. Laser tweezers are available for combined manipulation/trapping and imaging with other Octopus stations, and can also be used to study Raman spectra and pico-Newton forces between particles in solution for bioscience and environmental research. Two cryo focused ion beam scanning electron microscope (FIB-SEM) systems are also available. One is dedicated to 3D volume electron imaging, and the other, currently being commissioned, is dedicated to the preparation of lamellas and lift-out to prepare samples for cryo electron tomography. This latter system forms part of a correlative light and electron microscopy (CLEM) workflow currently under development.

Chemistry, biology, and spectroscopy laboratories support the laser facilities, and the CLF offers access to a multidisciplinary team providing advice to users on all aspects of imaging and spectroscopy, including specialised biological sample preparation, data acquisition, and advanced data analysis techniques. Access is also available to shared facilities in the Research Complex, including cell culture, scanning and transmission electron microscopy, NMR, and x-ray diffraction.

Engineering Services

Engineering is fundamental to all the operations and developments in the CLF. The engineering division operates across all of the CLF's facilities. Mechanical, electrical and software support is provided to deliver the experimental programmes, and the research and development activities. Support can range from making small-scale modifications to existing equipment to improve its performance, through to carrying out larger scale projects, such as the design and development of commercial projects. In addition, there are active engineering collaborations with regional and international partners such as, HiLASE (Prague, Czech Republic), the European XFEL (Hamburg, Germany) and TIFR (Hyderabad, India).

The CLF Engineering and Technology Centre (ETC) is now fully operational. The ETC brings all the engineering lab spaces together into a central hub. All engineering manufacturing and assembly areas are now in the same building, which makes collaborative working much easier. This year, the Electrical team completed its move to the first floor of the ETC. This brings the workshop technicians into the same area as the interlocks and control team's prototyping and development area, providing a working space that allows the sharing of skills. ETC is also an excellent area for the training of apprentices and development of staff.

The Centre for Advanced Laser Technology and Applications (CALTA)

CALTA aims to deliver societal, scientific and economic impact from developments in the CLF. CALTA continues to support the EPAC Project, which will use three DiPOLE-style amplifiers in its petwatt-class laser chain. The next generation of 100Hz DIPOLE lasers is also being developed as part of a Widespread teaming project. Construction of this new 100 Hz DiPOLE system is almost complete, and it is expected to break new ground in the coming year. Commissioning

of the D-100X laser system at the European XFEL continues, with the first two stages of the laser amplifier chain now commissioned and operating as expected. Completion of this system will be ready for user experiments later in 2023. The in-house DiPOLE 10 J laser was used to demonstrate a new laser shock peening (LSP) technique that does not require a water confinement layer. This will broaden the application space of LSP and unlocking the potential for higher repetition rate use, particularly in combination with CALTA's DiPOLE laser systems, for which the beam behaviour can be controlled closely and adapted for optimal results.

The Extreme Photonics Applications Centre (EPAC)

EPAC, a new facility at the CLF, will enable the development of a transformational generation of laser-driven radiation sources and accelerators, and will maximise their scientific and economic exploitation through engagement of multiple end-user communities.

EPAC will initially deliver a petawatt laser operating at 10 Hz to dedicated experimental areas housed in a stand-alone building. In order to achieve this high peak power and repetition rate, DiPOLE technology will be used to pump a high energy Titanium Sapphire amplifier operating at 10 Hz.

The first experimental area (EA1) will be especially designed for laser wakefield acceleration (LWFA), where multi-GeV electron beams and synchrotron-like x-ray beams can be generated. The second experimental area (EA2) will be a very versatile area for fundamental science and applications with flexible focusing geometries. A third experimental area is still to be specified.

The building was handed over last year and the installation of equipment into EPAC has started, with the focus on the second floor where the laser rooms will be the first areas brought online. STFC has provided additional funding to enable the design and fit-out of the two top floors of the east wing of EPAC.

The floors have been designed to house a mixture of open plan office space, collaborative zones and meetings rooms for staff and future users of EPAC.

Access to Facilities

The CLF operates "free at the point of access" and is available to any UK academic or industrial group engaged in open scientific research, subject to external peer review. European collaboration is fully open for the high power lasers, whilst European and International collaborations are also encouraged across the CLF suite for significant fractions of the time. Dedicated access to CLF facilities is awarded to European researchers via the Laserlab-Europe initiative (www.laserlab-europe.net) funded by the European Commission.

Hiring of the facilities and access to CLF expertise is also available on a commercial basis for proprietary or urgent industrial research and development.

Industrial access and partnerships

The Industry Partnership and Innovation (IPI) Group has been responsible for the delivery of the industrial access and establishing new collaborations with industry. The IPI group ensures that the interactions delivered are strategically aligned to the CLF and of the highest economic and societal impact to the UK. This year, industry contract-access projects has continued across all CLF facilities.

The CLF remains a strong department for innovation. Internationally, the CLF has driven forward its innovation policy and the growth of industry liaison offices, through shared learning and knowledge exchange across EU laser facilities as a project partner organisation on the European Horizon 2020 IMPULSE project.

Please visit www.clf.stfc.ac.uk for more details on all aspects of the CLF.