Overview of the Central Laser Facility (CLF)

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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 highly versatile 8 beam Nd:glass laser facility that operates to two independent target areas. The 8 beams can be configured in a number of combinations of long (>500ps) and short (<30ps) pulse arrangements.

Target Area Petawatt is Vulcan's highest intensity area, capable of 500J / 500fs pulses focused to 10^{21} W/cm^2. The ps OPCPA front end ensures that the ASE contrast of the PW system is better than 10^{10} at 1ns. To complement the short pulse beamline, an additional 250J long pulse beam line as well as a variety of possible probe beams can be configured in the area. This year a new seed oscillator has been purchased to replace an obsolete laser; this will be installed in future maintenance weeks.

Target Area West is Vulcan's most flexible target area offering up to 8 long pulse beams or 2 short and 6 long pulse beams. The two short pulse beams operate independently and can be configured so that one operates at 80-100 J / 1 ps (10^{20} W/cm^2) and the other one at either at 80-100 J / 1 ps or at 300 J / 10 ps in flexible geometries. TAW can also be configured with all 8 beams in long pulse mode by using a compressor by-pass arrangement delivering a maximum of 2.5kJ with all beams. Temporal pulse shaping is available for long pulse operation and there are a number of focusing, beam smoothing, probe beam and harmonic conversion options. This year there has been substantial investment in diagnostics to provide a larger suite of optical diagnostics for the community that can be shared when operating parallel experiments.

Gemini

This high rep-rate Petawatt laser based on Ti:Sapphire technology has a unique capability to offer 2 synchronised beams, each with a power of 0.5 PW and a repetition rate of one shot every 20 seconds. The facility will enable interaction studies up to 10^{22} W/cm^2. F/20 and F/2 beam focusing options are available, with a built-in plasma mirror set-up in one beam line for high contrast pulse delivery. In recent years the contrast of the compressed pulses from Gemini has been improved to the point where it is good enough for all but the most sensitive experiments, and for those the dual plasma mirror system is available. Both Gemini beam lines use adaptive optics mirrors to ensure the focal spot optimization on a routine basis: this has had a significant impact in the experimental delivery. In addition this year we have implemented a longer focusing geometry (F/40) in Gemini. The focusing optic is a spherical mirror and an adaptive mirror is used to correct for the aberrations arising from the focusing optic. Along with improved focal spots, this has yielded 2.5GeV electron bunches with nC charges in a recent experiment in Gemini.

Artemis

Artemis is the CLF's facility for ultrafast laser and XUV science. It offers ultrashort pulses at high repetition-rate, spanning the spectral range from the far-infrared to the XUV. The facility is configured flexibly for pump-probe experiments. Tuneable or few-cycle pulses can be used to generate ultrafast, coherent XUV pulses through harmonic generation or as pump and probe pulses. Two XUV beamlines lead to end-stations for atomic and molecular physics and condensed matter physics.

A new oscillator for the RedDragon was installed over summer 2015, and the long-term pointing stability of the laser is much improved. The stretcher and compressor gratings were also replaced in March 2016, the efficiency is now >70% and beam profiles are very good.

The Artemis lab has been re-arranged and the 45 degree table removed to provide a separate second XUV beamline, running parallel to the existing beamline. The new beamline consists of an HHG chamber, a flat-field spectrometer and a chamber for XUV imaging experiments. It provides increased space for filtering and beam separation.

The XUV monochromator has been upgraded with an additional grating at 830 lines/mm. This provides better energy resolution than the 300 lines/mm grating, but a factor of five less flux. For upcoming experiments, this will be compensated for by using 400 nm to generate the harmonics. On the monochromatised beamline, pump ellipticity measurements have now been implemented for users.

Octopus & Ultra (Research Complex)

The CLF operates two facilities in the Research Complex at Harwell: Ultra, for ultrafast molecular dynamics measurements in chemistry and biology, and Octopus, a cluster of advanced laser microscopes for life science research.

In the dynamics area Ultra offers a state-of-the-art high power 10 kHz fsec / psec system combined with OPAs to generate pulses for a range of unique pump and probe spectroscopy techniques. It provides spectral coverage from 200-12000 nm and temporal resolution down to 50fs. This is used in the investigations of fast photodynamic processes in solids, solutions and gases. Its time resolved resonance Raman (TR^3) capability enables highly fluorescent samples to be studied using a 4ps optical Kerr shutter. The Time-Resolved Multiple-Probe Spectroscopy (TRMPS) facility links Ultra with a 1 kHz ultrafast laser spectroscopy system, giving a femtosecond to millisecond pump-multiple probe spectrometer. The BBSRC funded Ultra station, LIFEtime, is a high repetition rate system (100 kHz) offering TRMPS capability for the investigation of biological systems. 2DIR spectroscopy capability is also available.

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. Microscopy techniques offered include total internal reflection (TIRF) and multi-wavelength single-molecule imaging, confocal microscopy (including multiphoton), fluorescence energy transfer (FRET) and fluorescence lifetime imaging (FLIM). Super-resolution techniques available are Stochastic Optical Reconstruction Microscopy (STORM) with adaptive optics, Photoactivated Localization Microscopy (PALM), Structured Illumination Microscopy (SIM) and Stimulated Emission Depletion Microscopy (STED). 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. A Light Sheet Microscopy station has recently been commissioned and is now available for users.

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

Mechanical, electrical and computing support is provided for the operation of the laser facilities at the CLF, for the experimental programmes on these facilities and for the CLF's research and development activities. Mechanical and electrical CAD tools and workshop facilities enable a rapid response.

Theory and Modelling

The CLF offers to support scheduled experiments throughout the design, analysis and interpretation phases, if required and within the resources available. We support principal investigators in data interpretation via radiation hydrodynamics, particle-in-cell, hybrid and Vlasov-Fokker-Planck modelling capabilities, as well as providing access to large-scale computing. One- and multi- dimensional radiation-hydrodynamic and atomic physics tools have been renewed for a further year, as endorsed by the CLF User Forum. The CLF will continue to provide support for student training in plasma physics and computational methods, alongside opportunities for networking with colleagues. Extended collaborative placements within the group are particularly encouraged.

Target Fabrication

The CLF is supported by an on-site Target Fabrication capability that integrates high specification microtarget design and production in collaboration with the user community. The facility deploys a wide range of complementary fabrication techniques in house such as thin film coating, precision micro assembly, advanced characterisation and chemistry processes, and leverages the unique position within STFC to fund and access high precision micro machining and MEMS fabrication of target components. The facility is ISO9001 accredited and is leading the way in providing a high level of characterisation and traceability that is essential for targets fielded in cutting edge research. The CLF is also responsible for the delivery of targets for the academic access to the Orion facility at AWE. Commercial access to target fabrication capabilities is available to external laboratories and experimentalists via the spin-out company Scitech Precision Ltd.

This year the chemistry laboratory has been converted into a cleanroom providing an environment ideally suited to the production of low density foam and aerogel microtarget components. Further advances have also been made on a high accuracy wheel system populated with MEMS-produced targets for future use in the Gemini target for high repetition rate solid target experiments. This will continue to be developed.

Centre for Advanced Laser Technology and Applications (CALTA)

CALTA was established in 2012 to develop diode pumped solid state lasers (DPSSLs), capable of delivering high energy pulses at high repetition rate, and to exploit this new technology in applications including advanced imaging, materials processing, non-destructive testing and fundamental science.

CALTA has already won contracts and grants in excess of £26M and is currently constructing two 1kW lasers based on its proprietary "DiPOLE" architecture. One has already been delivered to the HiLASE Centre in the Czech Republic where it will be used for materials studies and laser peening. The other will be supplied to the European XFEL facility in Hamburg for integration within the "HiBEF" end station, where it will be used to compress material to high density and the extreme states produced will be diagnosed by the synchronised XFEL x-ray beam. Assembly of the system for HiLASE was completed in September 2015 at RAL and a crucial milestone reached in the project on 21st October with the achievement of 107J output at 1Hz from the final amplifier. Following delivery to Prague, a joint HiLASE / STFC team will begin installing and commissioning the laser to its full 1kW specification in the new HiLASE building.

Design and procurement of major equipment for the XFEL laser is well advanced and assembly will commence in 2017 with delivery to Hamburg anticipated in mid-2018.

Other activity within CALTA during the year included collaboration with CLF's High Power Laser Division on the development of ultra-broadband optical coatings to enable the generation of 20-30 fs pulses for the production of high energy x-rays, ions and neutrons for advanced imaging and security applications.

Access to Facilities

Calls for access are made twice annually, with applications peer reviewed by external Facility Access Panels.

The CLF operates "free at the point of access", 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.

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

Economic impact

Innovation, the exploitation of exciting new ideas in a timely and efficient manner is inherent within CLF. The delivery of high Economic Impact (EI) forms an integral component of the CLF strategic objectives. This year we have continued to engage closely with industry and this has resulted in four companies gaining access to our facilities (Ultra, Gemini and Octopus). Three of these companies came through direct commercial contracts for proprietary access and the fourth through peer review in collaboration with a University group. Of particular note is the joint funding of a PDRA position with Johnson Matthey. This important step forward will enable much stronger links to be forged with both JM and wider industry. Additionally CLF attracted funding through The Proof of Concept scheme operated by the Business and Innovation Department to develop new ideas and technology focussed on Laser Peening and a new VUV source for processing waste materials.

This year has been particularly productive regards Intellectual Property generation and protection with a total of four patent applications filed. The IP reflects the broad range of sectors CLF covers and includes nuclear waste imaging, characterising ultra-short pulses, new laser alignment methods and novel biomarkers. CLF continues to take the lead in terms of invention disclosures and patent ideas submitted for review. To broaden their market reach and activities portfolio, CLF spin-out Cobalt Ltd. has recently started working with STFC and two UK Universities, with funding from EPSRC on research that could lead to medical-grade systems that provide on-the-spot diagnosis of breast cancer and bone diseases such as osteoporosis. Whilst Scitech Precision Ltd. another CLF spin-out can now offer a laser micromachining service, having taken on two new members of staff and purchased equipment from a local company Micronanics.