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

Target Area Petawatt is Vulcan's highest intensity area, capable of 500 J /500 fs 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}. To complement the short pulse beamline, an additional 250 J long pulse beam line, as well as a variety of possible probe beams, can be configured in the area. This year we have been investigating the contrast and have identified a number of pre-pulses that were caused by post-pulses in the OPCPA pre-amplifier. These have been removed by the use of wedged optics.

Target Area West is Vulcan's most flexible target area, offering up to eight long pulse beams, or two short and six 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 either at 80-100 J / 1 ps or at 300 J / 10 ps in flexible geometries. This year the mirror mounts on the CPA beam lines have been modified as part of the continuing work to improve focal spot quality.

In addition, there has been substantial investment in the long pulse provision in TAW, by upgrading the final lens focusing mounts and by installing a compressor by-pass arrangement to enable TAW to be used with all eight beams in long pulse mode. The maximum energy that can be delivered is 2.5 kJ when all eight beams are configured for long pulse operation. 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 we have worked on improving the stability of the long pulse shaping system employed in TAW and have improved the pulse to pulse energy stability to ~5%.

Gemini

This high rep-rate Petawatt laser based on Ti:Sapphire technology has a unique capability to offer two synchronised beams, each with a power of 0.5 PW and a repetition rate of one shot every 20 seconds. The facility enables interaction studies up to 10^{22} W/cm^2. F/20 and F/2 beam focusing options are available as standard, with a built-in plasma mirror set-up in one beam line for high contrast pulse delivery. There have been several improvements on the temporal contrast of Gemini pulses in recent years; this year has seen the implementation of a transmission grating-based stretcher in Gemini in order to improve its coherent contrast. There has also been a major improvement in the focal spot quality obtained in Gemini. A new wavefront diagnostic technique after the farfield, along with the versatile deformable mirrors, has yielded ~60% encircled energy in a two micron spot for F/2 focusing. As a result of these improvements, the maximum proton energies obtained in Gemini have increased significantly.

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 can be used as pump and probe pulses.

Two XUV beamlines lead to end-stations for atomic and molecular physics and condensed matter physics. One beamline contains a monochromator to select a single harmonic from the spectrum while preserving the 30 fs pulse length. Wavelength selection on the second beamline is obtained through filtering and multilayer mirrors.

Artemis offers a variety of end-stations for time-resolved spectroscopy and imaging. The UHV end-station offers time-and angle-resolved photoemission spectroscopy (ARPES). A second UHV chamber for time-resolved photoemission on magnetic samples has been commissioned. This chamber is equipped with a low noise level electron time-of-flight analyser, magnetisation coils and MOKE. The atomic and molecular physics end-station contains a velocity map imaging detector and differentially pumped gas source. A coherent XUV imaging chamber with multilayer focusing mirrors and sample positioning has also been installed.

This year the development work on Artemis has continued to focus on widening the range of experiments offered. We have continued to develop gas-phase photoelectron spectroscopy experiments with XUV probes, and have now increased the XUV flux at target by a factor of 30, by using the second harmonic at 400 nm as the HHG drive pulse. The hollow fibre pulse compressor was recommissioned this year and used to obtain sub-10 fs temporal resolution and sub-eV energy resolution in a NIR-pump XUV-probe photoelectron spectroscopy experiment on graphene. We have also started a development in collaboration with Imperial College on few-cycle idler pulses at 1.8 micron, to be able to generate harmonics in the water window.

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 fs / ps system combined with OPAs, to generate pulses for a range of unique pump and probe spectroscopy techniques. It provides spectral coverage from 200-12,000 nm and temporal resolution down to 50 fs. This is used in 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 4 ps 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. A new BBSRC-funded Ultra station, LIFEtime, has recently been installed and is currently being commissioned using selected projects. Capital funding has been provided to upgrade the Ultra system with a new 20 W laser that will improve performance for a number of techniques, and enable parallel operation, allowing Ultra operations to be increased from 40 to 60 user weeks per year. A technician is being recruited to support the increased level of operation.

In the imaging area, the Octopus cluster offers a range of microscopy stations linked to a central core of pulsed and CW lasers providing '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); and single molecule Alternating Laser Excitation (ALEX) in both confocal and TIRF modes. 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. Additional funds have been made available to increase the number of user weeks offered by Octopus from 60 to 100 per year. To support the higher level of operations, two new Link Scientists have been appointed, with expertise in super-resolution microscopy.

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 will offer to support scheduled experiments throughout the design, analysis and interpretation phases, if required and within the resources available. We offer hydrodynamic, particle-in-cell, hybrid and Vlasov-Fokker-Planck modelling capabilities, and access to large-scale computing. Parallel computing resources include the SCARF system, and the CLF purchased assets, LEXICON 1 and LEXICON 2. In early 2016 we anticipate the commissioning of a new asset, SCARF-MAGNA-CARTA, which will be a 256 core resource. New 1D and multi-dimensional radiation-hydrodynamic and atomic physics tools have been renewed for a further year, as endorsed by the CLF User Forum. Student training in computational methods, and opportunities for networking with colleagues, will continue to be provided. Extended collaborative placements within the group are particularly encouraged.

Target Fabrication

A high capability target fabrication facility is operated within CLF, delivering advanced microtargetry to experiments. The facility offers a wide range of integrated target production techniques, such as microassembly, thin film coating (including ultrathin carbon), and low density foam production. Many microcomponents are produced in collaboration with the STFC micromachining and MEMS facilities. Multiple characterisation techniques underpin all microtarget production and R&D programmes. Target Fabrication continues to be ISO9001 accredited. Commercial access to target fabrication capabilities is available to external laboratories and experimentalists via the spin-out company Scitech Precision Ltd.

As the result of a sustained R&D programme over the last year, it is now possible to offer cryogenic deuterium film ice targets. During the reporting year a dedicated chemistry laboratory, operating under cleanroom conditions, has been commissioned. The new laboratory has allowed a wider range of low density polymer targets to be offered at much higher yields. Additionally chemistry-based techniques have been extended to produce ultrathin (few nm) plastic films. We have developed a programme to address high repetition rate requirements, HAMS (high repetition rate microtargetry system), which aims to integrate microtarget mass production and rapid positioning.

Centre for Advanced Laser Technology and Applications (CALTA)

CALTA is a new STFC/CLF Centre that is charged with driving forward next generation laser technology, principally focused on the industrial and commercial application of high power lasers and the by-products of interactions (e.g. super bright, high energy photons, electrons, ions, etc). At its heart is a campaign to develop advanced, proprietary diode-pumped laser technology (DiPOLE) and associated multi-PW component technology that has been pioneered within the CLF in recent years. The main activity within DiPOLE is the development of a scalable diode-pumped solid state laser (DPSSL) concept that is capable of delivering kJ-level pulses at a repetition rate of 10 Hz or above. A conceptual design of a cryogenic Yb:YAG amplifier has been developed that can be scaled to kJ energy levels and beyond, due to its geometry, unique laser design and cooling technique.

A lower-energy DiPOLE prototype amplifier system has been built and is currently operational, routinely delivering 7 J /10 Hz with good energy stability. This year CALTA has focused on the delivery of a £10.3M contract to supply a 100 J DiPOLE to the HiLASE project in the Czech Republic. The system has been built in a CLF cleanroom and commissioning has started. The aim is to demonstrate base line design and then to ship the system to the HiLASE team for installation and final commissioning on their premises in the Czech Republic.

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 Laser Lab-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.

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 and the overall delivery plan.

This year we have generated impact by:

- A ground breaking experimental run in Vulcan TAW, demonstrating the capabilities of Laser Driven Sources for the imaging of complex samples, relevant across a number of industrial sectors;
- Engaging and partnering with industry by winning contracts with companies to enable access to our facilities;
- Winning bids through H2020 for Widespread and Teaming, and the Newton Fund for collaborations with China, India and South Africa;
- Filing new patents in the area of super-resolution molecular imaging;
- Building and supporting our spin out companies;
- Engaging with the public, in particular through *International Year of Light* activities.

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