Overview of the Central Laser Facility (CLF)

Cristina Hernandez-Gomez
Central Laser Facility, STFC Rutherford Appleton Laboratory, Harwell Campus, Didcot OX11 0QX, UK
Email address: cristina.hernandez-gomez@stfc.ac.uk Website: www.clf.stfc.ac.uk

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 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} at 1 ns. 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. A compressor has been installed in the Vulcan front-end to help with characterising the contrast and for the development of new short-pulse diagnostics.

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 be also be configured with all 8 beams in long pulse mode by using a compressor by-pass arrangement delivering a maximum of 2.5 kJ 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 an upgrade to the Vulcan timing system, to reduce the temporal jitter between the long and short pulses by an order of magnitude to 20 ps RMS.

Gemini

Gemini is a Titanium-Sapphire based dual-beam high power laser system with the unique capability of 2 synchronised Petawatt-class beams, enabling interactions at extreme light intensities (~10^{22} W/cm^2). Gemini's dual-beam capability enables cutting-edge experiments that are difficult to perform in other facilities around the world. This year, Gemini performed several experiments - ranging from Thomson scattering to investigate Quantum corrections to gravity and demonstrating radiation reaction as near-light-speed electrons are slowed down in intense light fields, to investigating novel injection mechanisms for laser wakefield acceleration - utilising this capability. In recent years, Gemini has established itself as one of the preeminent centres for laser-driven wakefield acceleration and applications. An experiment in Gemini's Astra Target area last year demonstrated feedback-control of high-energy laser-driven electrons at high-repetition rate for the first time, while another experiment in Gemini investigated novel injection mechanisms to improve laser-driven electron acceleration.

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 XUV to the far-infrared. The facility is configured flexibly for pump-probe experiments. Tuneable or few-cycle pulses can be used as pump and probe pulses, or to generate ultrafast, coherent XUV pulses through harmonic generation. Two XUV beamlines lead to end-stations for time-resolved photoelectron spectroscopy (for both gas-phase and condensed matter experiments) and coherent lensless XUV imaging. This year saw Artemis's first demonstrations of UV-pump XUV-probe photoelectron spectroscopy from gaseous molecules, and also its first demonstration of XUV lensless imaging from biological molecules.

Artemis has received funding for a 100 kHz laser system operating at 1700 nm and 3000 nm, in a joint purchase with Ultra. The laser system will be installed and commissioned in 2018.

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 200-12,000 nm and temporal resolution down to 50 fs. 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 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. 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. An IR pulse shaper on the Ultra B station enables broadband 2DIR experiments on highly scattering samples.

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), Stimulated Emission Depletion (STED) Microscopy, and Light Sheet 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. A new facility offering super-resolution microscopy at cryogenic temperatures 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 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. We support principal investigators using radiation hydrodynamics, particle-in-cell, hybrid and Vlasov-Fokker-Planck codes, as well as by providing access to large-scale computing. Access to the PRISM suite has been renewed for a further year, as endorsed by the CLF User Forum. Support for student training in plasma physics, computational methods and opportunities for networking with colleagues will continue to be provided. Extended collaborative placements within the group are particularly encouraged.

Target Fabrication

The Target Fabrication Group makes almost all of the solid targets shot on the CLF's high power lasers. A wide variety of microtarget types are produced in collaboration with the user community to enable the exploration of many experimental regimes. The integrated range of fabrication techniques includes thin film coating, precision micro assembly, laser micromachining, and chemistry processes, all verified by sophisticated characterisation. Additionally the advanced capabilities within STFC in both high precision micro machining and MEMS microfabrication are utilised. The Target Fabrication Group is ISO9001 accredited and consequently provides a high level of traceability for all supplied microtargets. The Group is also responsible for the production of targets for academic access shots on 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.

In the reporting year the Target Fabrication chemistry laboratory was commissioned and began production of low density foam and aerogel microtarget components. To address the opportunities for high repetition rate solid targets on Gemini, the high accuracy target wheel system was proven to be compatible with MEMS-produced targets under experimental conditions. The design of the CLF cryogenic hydrogen target was refined to enable operation at lower temperatures.

Centre for Advanced Laser Technology and Applications (CALTA)

The CLF's Centre for Advanced Laser Technology and Applications 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 its second 1 kW laser based on its proprietary "DiPOLE" laser architecture. The first has been delivered to the HiLASE Centre in the Czech Republic, where it is being used for materials studies and laser peening. The second will be supplied to the European XFEL Facility in Hamburg for integration within the high energy density (HED) end station. 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.

Delivery of the system to HiLASE was completed in early 2016, followed by installation and commissioning by a joint STFC / HiLASE team. In December 2016 the DiPOLE100 system was demonstrated at full capacity, becoming the first system of its kind in the world to operate at 1 kW. The build of the second DiPOLE100 system for the European XFEL laser is well advanced, with the optical tables and front end system already installed. Final commissioning of the system will take place at RAL, prior to packaging and delivery to Hamburg at the end of 2018.

2017 saw the start of a Horizon 2020 Widespread Teaming Project, a collaboration between STFC and the Czech Institute of Physics to establish a laser applications "Centre of Excellence" at HiLASE. The €50M project is jointly funded by the European Commission and the Czech Ministry of Science. STFC will assist with the establishment of the Centre and play a leading role in the development of advanced DPSSL technology. This includes the design and construction of a 100 Hz version of the DiPOLE 10J laser. This will extend STFC's lead at the forefront of DPSSL laser technology.

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

A major aspect of our Economic Impact work this year was in the establishment of a contract with DSTL for a full and detailed Technical Design Review for the PULSAR project. This involved significant negotiation and planning. The PULSAR TDR was successfully completed and delivered during this reporting year.

Relationships with industry continue to be built, and in total five new commercial contracts were established for access to Ultra, Octopus and Gemini. Importantly we have identified three new areas for engagement with Rolls Royce: laser peening, laser driven sources for Non Destructive Evaluation and fluid inspection within large and complex gear box and engine systems.

An important international highlight was the phase 2 proposal submitted to the European Commission under the H2020 Widespread and Teaming initiative with HiLASE in the Czech Republic. This proposal was successful and will allow CALTA to develop the DiPOLE technology to higher energy and higher repetition rates. The CLF also leads on the Innovation work package and has formed an innovation task force for the project to support the industrial take up and exploitation of high power lasers and their applications. This is a circa €50M programme funded jointly by the European Commission and the Czech Ministry, with 20% of the funds allocated directly to CLF.